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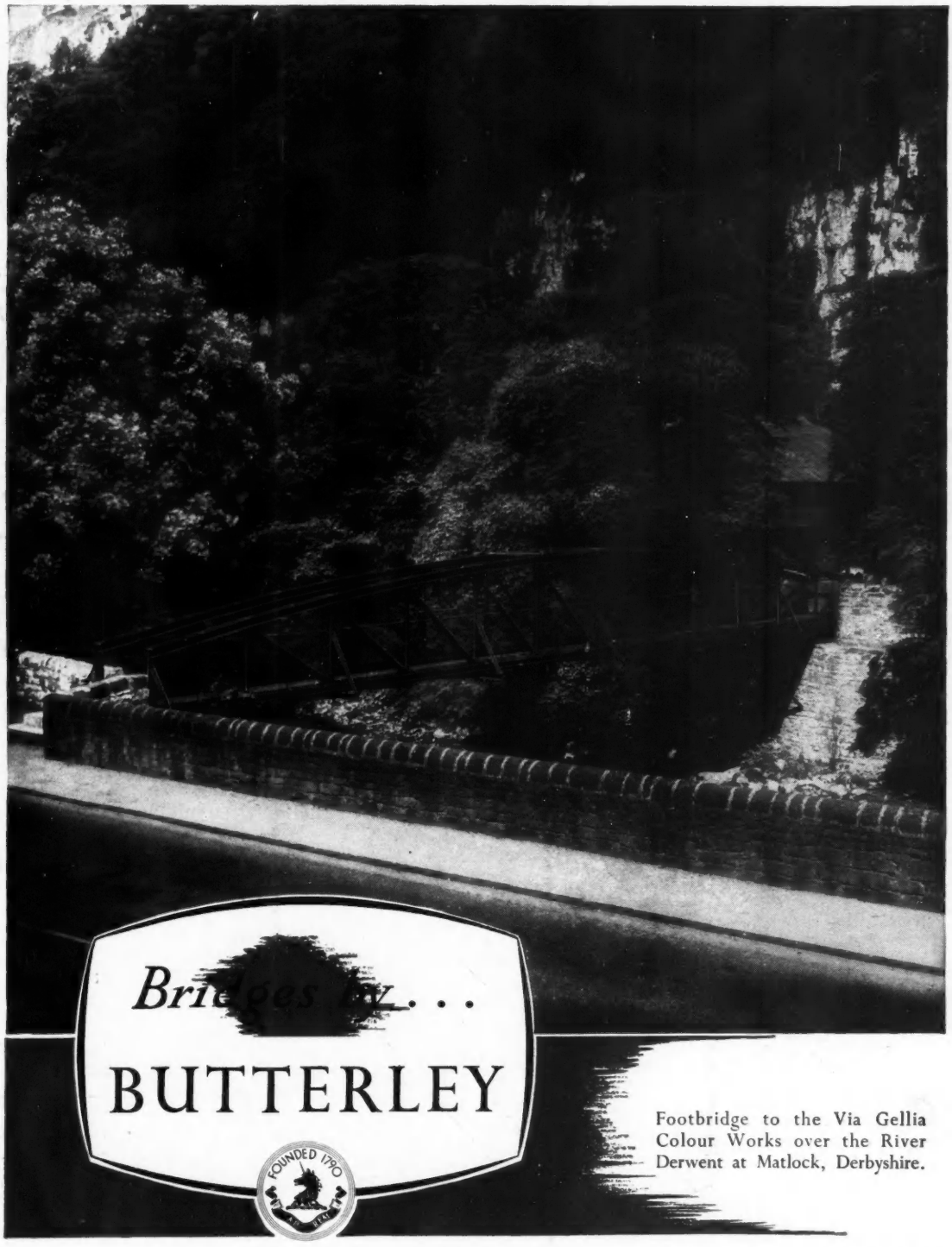

Footbridge to the Via Gellia Colour Works over the River Derwent at Matlock, Derbyshire.

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YEARS

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Productivity in British Industry*

No. XV—SAFETY IN INDUSTRY

By SIR ALFRED HERBERT, K.B.E.

MUCH of the information contained in these notes is, of necessity, based on experience gained in the company with which I have been so long associated, and my apologies are made for the frequent references to our works and our practice.

Accidents have been described as Acts of God. It is surely better to regard them as Acts of the Devil, and to fight the Devil with fire; any other attitude begets complacency, which in every field of human endeavour is the father and mother of failure.

The nightmare of workshop accidents has haunted my sixty-five years of otherwise happy working life. Although during that long span there has been a steady improvement in factory conditions and a growing consciousness of the importance of safety in industry, much still remains to be done.

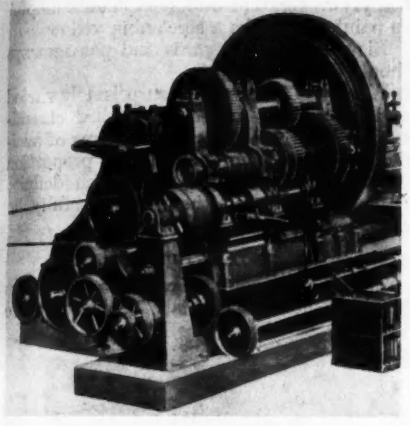

FIG. 1—UNGUARDED HEADSTOCK OF HEAVY LATHE 1919

The following figures, for which I am indebted to Mr. Barnett, the Chief Inspector of Factories, give some idea of the size of the problem which confronts us.

During 1948, 201,086 notifiable accidents (861 of them fatal) occurred at premises subject to the Factories Act. These figures may be sub-divided into :—

(i) Factories	182,838, of which 552 (a proportion of 1 to 33) were fatal.
(ii) Docks and Warehouses	7067, of which 52 (1 to 36) were fatal.
(iii) Building operators and works of engineering construction.	11,181, of which 257 (1 to 43) were fatal.

In Coventry, with a population of about 250,000, there were reported to the District Inspector of Factories in 1948, 2729 accidents, of which three were fatal, a proportion of 1 in 909. Of these accidents 24·5 per cent were due to the handling of goods, 19 per cent to power machinery; the remainder to falls and a great variety of other causes.

I am informed that something like 7500 works' accident cases were brought to the casualty department of our local hospital in twelve months and that attendances at the casualty department averaged about two and a half times the number of new cases so that 15,000 to 20,000 attendances are annually recorded. These figures, which, of course, are only approximate, show a very large increase over those reported to the Factory Inspectors and obviously include many cases not covered by the official statistics. They serve to show in striking fashion the great demand which accidents make on the already overworked medical, surgical and nursing staffs of our hospitals, as well as the great loss of working hours involved.

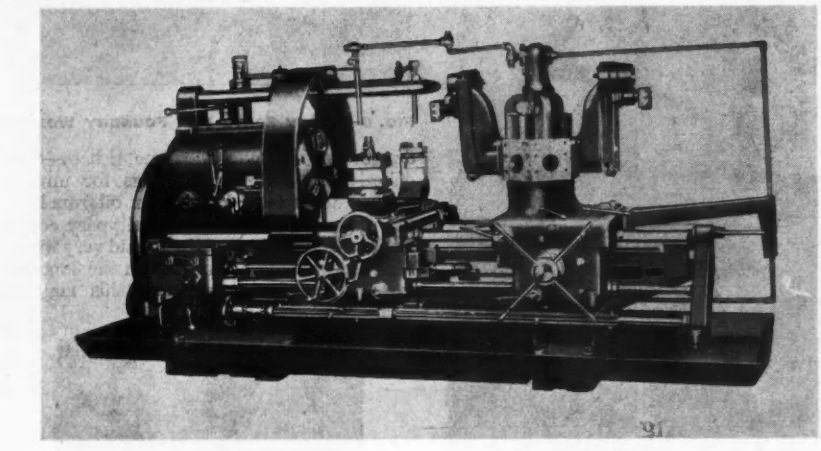

FIG. 2—MODERN LATHE WITH ALL GEARINGS GUARDED

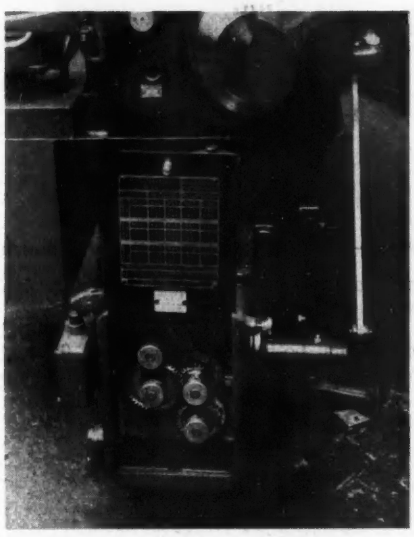

FIG. 3—GEARBOX COVER INTERLOCKED WITH POWER SUPPLY

Looking back through the years to my apprenticeship at an engineering works in Leicester, the progress in regard to the prevention of accidents and in the treatment of the injured has been full of encouragement. Then there was practically no attempt to fence dangerous machinery, and machine tools bristled with naked gears and death traps. Belt driving was universal, for the electric motor was a thing of the future. Speeds were changed by cone pulleys, and we handled the belts with complete indifference to the risks involved, becoming expert in flicking them on to the desired step of the overhead cone without using the belt sticks provided. Two drilling machines provided for use by the fitters stood side by side (Figs. 1–3). In one of them the hand-wheel was immediately above the unguarded bevels and in the other just below. Imagine the risk in using first one and then the other! My fingers touched the bevel gears more than once, but by sheer luck they were never caught.

Major accident cases went to hospital in the nearest available cab. The slightly injured walked to a neighbouring chemist's shop for treatment, or had their wounds bound up with rag soaked in Friar's Balsam (by the way, an excellent germicide). Splinters of metal were removed from eyes by one of our mates, quite an expert at the job. The patient stood with his head against the wall, while the operator everted the eyelid with a match-stick and removed the splinter by scraping with the very sharp but by no means very clean blade of his pocket-knife.

In contrast with these primitive arrangements, most factories to-day are provided with surgeries for the prompt treatment of minor injuries. Trained nurses and in many cases, whole-time or part-time doctors are in attendance, and ambulances are available for quick removal to hospital of the more serious cases. Safety officers devote their whole time to investigating past accidents and to devising ways of preventing future ones. In many of the larger factories dental and electrical treatment of various kinds is also provided and these facilities not only ensure prompt treatment, but save a great deal of time in attending public institutions, where long waits are inevitable and where in some cases appointments for physiotherapy have to be made two or three months in advance.

Attention may now be called to some general conditions, which, from a safety

* No. I, "An Introductory Survey," by B. White, appeared February 17th; No. II, "The Threshold of Productivity," by F. A. Martin, March 3rd; No. III, "High Productivity and Production Costs," by Sir Claude Gibb and Gordon M. Baker, March 17th; No. IV, "Standardisation in the Aircraft Industry," by E. C. Bowyer, March 31st; No. V, "Restrictive Practices," by Arthur Woodburn, April 21st; No. VI, "Research for Productivity," by Dr. D. F. Galloway, May 19th; No. VII, "Consequences of Simplification," by W. D. King and H. Sherburn, June 30th; No. VIII, "Works Extensions," by C. K. F. Hague, July 28th and August 4th; No. IX, "Mechanical Handling," by F. Garner and A. Siddall, August 11th and 18th; No. X, "The Importance of the Craftsman," by F. V. Everard, September 1st; No. XI, "Productivity in the Smaller Engineering Works," by Antony Vickers, September 15th; No. XII, "Productivity in Civil Engineering," by Lieut.-Colonel C. M. Norrie, September 29th; No. XIII, "The Measurement of Productivity," by L. H. C. Tippett, October 13th; No. XIV, "The Contribution of the Machine Tool Industry," by J. B. S. Gabriel, October 0th.

point of view (and indeed from many others), are desirable in factories.

Light

The dark and grimy workshops, which were by no means uncommon at the beginning of the century, have mostly disappeared and nowadays we are keen to take full advantage of daylight, which costs us nothing if we will only let it enter freely. In the vivid Biblical

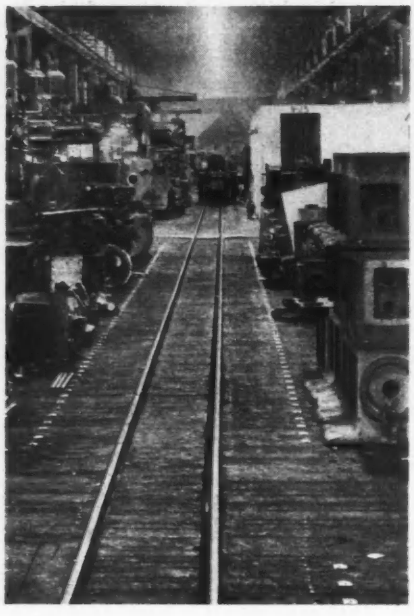

Fig. 4—Clearly Defined Unobstructed Gangway

story of the beginning of things the first fiat was "Let there be light," and in the glory of that light the six days labour of creation was accomplished. Artificial lighting, too, is usually adequate; electric lighting in various forms is universal and the old fish-tail

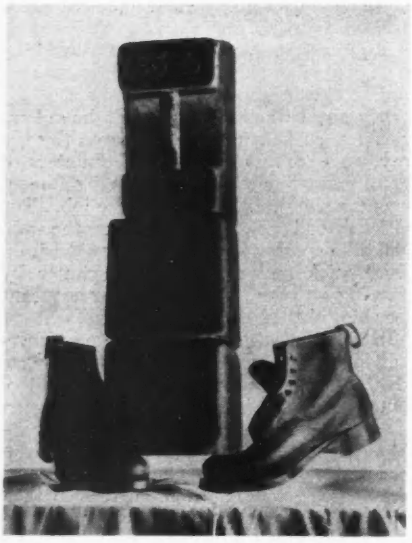

Fig. 5—Safety Boots with Reinforced Toe Caps

gas burner on which we used to depend has become a museum piece.

Floors

A very large proportion of accidents in workshops, in homes and in the streets occur through falls, most of them caused by stumbling over unsuspected obstructions or irregularities or by slipping. The moral is obvious; all gangways should be clearly defined by white lines or metal studs and should be kept clear of material of all kinds (Fig. 4): nothing is more

Fig. 6—Safety Spats for Foundry Worker

dangerous than cylindrical metal bars—very effective anti-friction bearings for unwary feet. Care is needed to prevent oil from leaking on to floors and causing slippery conditions. An American engineer said very wisely that there should be nothing on the floor of a factory but feet, and while this may be

Fig. 7—Injured Foot of Foundry Worker

a counsel of perfection, it is well worth remembering.

The use of stillages and containers and conveyors, both for materials and finished work, should be encouraged; not only are

Fig. 8—Goggles Splashed by Molten Metal

floors kept much clearer, but a great deal of unnecessary labour in picking up things from the floor and putting them back again is saved. By the use of forked elevating trucks a number of stillages can be packed quite safely one on the other, and thus the amount of stuff on the floor is much reduced. The expression "floor to floor time" which is often used in estimates of machine output is outmoded and should, I think, be superseded by "stillage to stillage time." But the mechanical trucks themselves, which nowadays weave their way through our factories, are by no means free from danger to the heed-

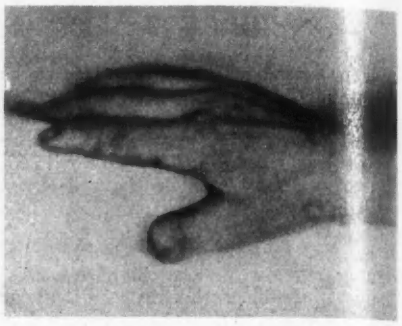

Fig. 9—Thumb Lost Through Sepsis

less jaywalker, and we have found it helpful to paint our trucks a screaming yellow.

Bicycle riding in yards and passageways should be forbidden.

Workshop accidents are surprisingly varied and unexpected and defy detailed classification, but there are several groups of accidents which account for a great proportion of our troubles and against which definite remedies exist, and these may usefully be considered.

Foot Injuries

These are common amongst labourers handling heavy materials, while machine

Fig. 10—Properly Clothed Foundry Worker

operators and fitters, who frequently drop work pieces of considerable weight from benches or from the tables of machines, are by no means exempt. Similar mishaps are common in foundries. Accidents of this kind can be almost entirely avoided by the use of safety boots with rigid internal steel toe-caps. These boots (Fig. 5), which are in every way comfortable and satisfactory to wear, are usually carried in stock in most modern factories and are very cheap. The trouble is to induce

people to wear them. I have been accused more than once of having safety boots on the brain and my answer is that I shall continue to have them on my brain until a larger proportion of people have got them on their feet.

During 1944, sixty-six of our people injured their feet. It is considered that fifty-nine of these accidents would not have occurred if safety boots had been worn. Since then many more workers have been persuaded to wear safety boots, and our foot injuries during 1949 were reduced to twenty-seven, and of these, at least fifteen were due to the lack of safety boots.

In foundries safety boots are even more necessary, and by the addition of stout leather spats (Fig. 6), foot injuries from splashes of hot metal are greatly reduced. Even a small globule of molten metal burns its way through ordinary boots and finishes up in the foot (Fig. 7), whereas the leather spat sheds a splash of metal harmlessly like water from a duck's back.

FIG. 11—SUITABLY DRESSED MACHINE OPERATOR

FIG. 12—UNSUITABLY DRESSED MACHINE OPERATOR

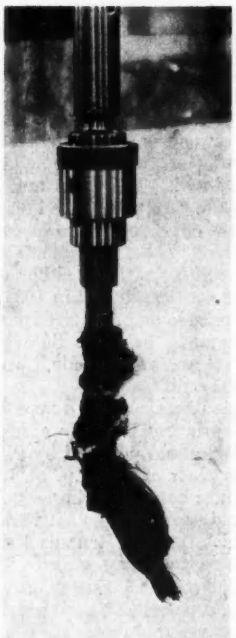

FIG. 13—RESULT OF DRILLING MACHINE OPERATOR WEARING LONG SLEEVES

EYE INJURIES

These occur with deplorable frequency in metal workshops. They are caused chiefly by splinters and chips of metal, by fragments of abrasive wheels and by sparks and splashes in the foundry. Against these accidents the wearing of goggles or visors gives almost certain protection, and here again it is noted with regret how exceedingly difficult it is to induce operators to take these precautions, although the necessary appliances are always available.

Still, there has been considerable improvement, for in 1944 twenty-two eye injuries occurred in our shops, of which nineteen would have been prevented by goggles (Fig. 8) or visors. In 1949, by the extended use of these protectives, our eye injuries were reduced to ten, and most, if not all, of these would not have occurred if goggles or visors had been worn.

One of our factory inspectors recently told a story which illustrates the optimistic attitude of workers, who take unwarranted risks. Two fettlers were chipping the flashes from a large casting, one of them was wearing goggles, the other disdained this precaution. He was asked why he was not following his friend's good example. "Oh, him," he said, "He's only got one eye left." Among our collection of relics we have a large number of damaged and broken lenses. It is a cheering thought that each damaged lens means an undamaged eye. In one case a splash of molten iron flew up and broke the goggles of the driver of an overhead crane, but his eyes escaped.

SEPSIS

We are surrounded by germs eager to take advantage of any breach, however slight, in the defences of our healthy skins and to set up painful sepsis and inflammation (Fig. 9). The first precaution before a surgical operation is to sterilize the patient's skin and the instruments, swabs and bandages, as well as the hands of the operator and nurses, who also wear sterilized aprons and cover their faces with masks to protect their patients from risk of infection from the germs, which are always present in mouths and noses. With these precautions a surprising number of operation wounds heal without subsequent inflammation and patients, who formerly would have spent three or four weeks in bed, are now up and about in a few days, thanks to Lister, the pioneer of modern surgery. Yet how often do we find that trivial cuts and abrasions are neglected and result in painful sepsis and suppuration entirely preventable by a prompt visit to the surgery and immediate sterilisation?

STRAINS AND RUPTURES

Lifting appliances are generally available in the modern workshop, but I do not believe that sufficient numbers of them are even now provided. It is hard to draw the line between weights which can safely be lifted and those which demand the use of a crane. A strong and healthy man, who knows how to lift a job, can frequently handle without injury or distress, weights which would involve considerable risk to a lad, a woman or a weakling, and the only general guidance that can be given is that no one should persist in attempting to lift a job which causes the slightest feeling of stress or strain. To pick up weights safely from the ground, the hands should be kept as near as possible to the legs and the worker should bend his knees and thighs to bring his hands into contact with the work and should do the lifting by the powerful muscles of the thighs and legs, thus avoiding the strain which is so liable to injure the abdominal muscles when bending forward to reach the job.

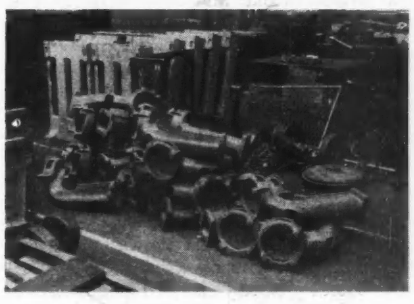

FIG. 14—DANGEROUSLY STACKED PILE

DERMATITIS

While most healthy and uninjured skins have great resisting power, there are a number

of people whose skins are deficient in this respect, and who are, in consequence, liable to skin infections, particularly if their hands and arms are exposed to the oils and coolants used on machines. Oils should be sterilized by heat at regular intervals and a percentage of "Dibactol" or other germicide should be added to coolant oils. There are protective ointments for the arms and hands, but if a man shows a definite tendency to contract dermatitis he should be given a job which does not involve exposure to oil risks.

Protective Clothing

All machine workers should be suitably clad. Overalls should have tightly-fitting sleeves, or better still, no sleeves beyond the elbow (Fig. 13). Clothing should be close fitting and the hair of female operators should be completely covered by suitable caps (see Fig. 11). Bracelets (Fig. 12), long sleeves (Fig. 13), and even rings, are liable to entanglement. High heeled shoes are frequent causes of falls.

Stacking of Work

As already pointed out, the use of stillages which can be mechanically and safely stacked avoids many risks, but castings and other materials too bulky for stillages are often stacked in careless and dangerous ways. A man trying to pull out one casting from a pile (Fig. 14) is always liable to cause an avalanche of other castings, which may cause him to be seriously hurt.

(To be continued)

Fast Railcar Services on the Continent

(By a Correspondent)

THE observant traveller on the Continent must notice a certain liveliness in the 1950 train services, much of it stimulated, no doubt, by the Holy Year traffic. There is, for example, "Il treno dell'Anno Santo" on the Italian railways which enables a passenger to leave Rome at 9 a.m. and reach Lausanne at 10 p.m. Stoppages at frontier points impose their toll and powerfully affect the inclusive journey time, so that the greater part of the acceleration is found inside the respective frontiers. For example, on the Italian railways, one may now depart from Milan at 2.30 p.m. and reach Rome at 8 p.m. In France, the 512km (318 miles) between Paris and Lyon is covered by train No. 41 in 295 min, or at the rate of 104·1 km.p.h. These and other fast railway journeys are performed, of course, by light or medium light trains. "Il treno dell'Anno Santo" has seats for only 160 passengers and the fast services between Paris (Est) and Bâle are maintained by single railcars ("Autorail Rapide"). It is these fast French railcars which are the subject of the present article, and whether or not they remain as permanent features of the traffic working on the Eastern Region of the C.N.C.F., the "Autorail Rapide" is something which does suggest enterprise and certainly makes a profound difference to the time taken in transporting a passenger by rail from Paris to Bâle and vice-versa.

There are two services in each direction. East-bound, the railcars leave Paris (Est) at 7 a.m. and 6 p.m. West-bound, the departure times from Bâle are 7.05 a.m. and 6.05 p.m. The inclusive time allowed on the east-bound journey is 326 min for the 526km between Paris (Est) and Bâle. West-bound, the booked time is 1 min less. There are stops, in both directions, at Belfort and Mulhouse. A small supplement is charged on the normal first and second class fares, the accommodation being strictly limited.

By using this service, the passenger travelling eastward by the "Golden Arrow" can, after sleeping the night in Paris, reach Bâle at 12.26 p.m. on the following day and he has the opportunity of comparing the running of the steam-hauled Pullman trains on each side of the Channel with the "Autorail Rapide." The comparison is, of course, one of train weight and speed, since in the case of the "Golden Arrow" service from Victoria to Dover (via Bromley-Petts Wood-Tonbridge-Folkestone) the conditions are not conducive to high average speed when the trailing load goes to, say, 430 tons. With trains of this weight, whether east-bound or west-bound, the powerful "West Country" class locomotives rarely complete the journey in less than 94 min for the 78 miles, giving a mean speed, start to stop, of 50 m.p.h., or, say, 80 km.p.h. This is, indeed, a good performance over such a route with a train of the given weight.

The "Autorail Rapide" with a loaded weight of from 40 tons to 43 tons according to the type of railcar used, covers the 327 miles between Paris and Bâle in 326 min, giving an average speed (inclusive of stops) of rather more than 60 m.p.h. (96·4 km.p.h.). In considering this performance, it is necessary to know something of the configuration of the route and, before giving the logs of two recent journeys, it may be explained that the line from Paris (Est) to Bâle, via Chaumont-Belfort-Mulhouse, is on a slightly rising grade for the first 30km. Thereafter, it descends until reaching km-post 50, where commences a moderate climb to km 77, whence there is a fairly steep descent to km 95 beside Flambouin. From this point through Nogent-sur-Seine, Romilly and Troyes to the summit at Vauchonvillers (km 205) the line steadily rises and after a sharp descent for 10km to Arsonval-Jaucourt the rise is resumed with increasing steepness through Bar-sur-Aube, Clairvaux and Bricon to the summit at Chaumont (261·5km). Falling again to Luzy (270km) the rise recommences through Vesaignes, Humes and Langres to km 303, whence there is a sharp descent continuing for 25km through Chalindrey and Hortes to La Ferte-sur-Amance (328km). This is followed by a fairly level stretch to Port-d'Atelier (360km). Thence through Vesoul and Lure, the line after undulating for short stretches, climbs to km 430, this rise including the stiff gradient extending from Lure (411km) to the summit near Champagney. The railway then falls sharpley to Belfort (443km), whence the remainder of the journey through Mulhouse to Bâle (526km) is gently downhill. The gradients in either direction are not severe, about 1 in 166 being rarely exceeded though there are some comparatively long stretches at this rate, notably between Maranville and Chaumont and between Lure and Champagney.

The accompanying log gives particulars of a journey made between Paris-Est and Bâle on the "Autorail Rapide" which leaves Paris at 7 a.m.

"Autorail Rapide" (Train No. 41).—Paris-Est to Bâle, April 23, 1950.—de Dietrich Railcar No. XD 2630, S.N.C.F.—Log of Run

	Booked h. m. s.	Actual h. m. s.
Depart Paris-Est	7 00 00 ...	7 01 40
Pass Noisy-le-Sec (8·5km) ...		7 10 00
Pass km-post 120		8 11 40
Pass Romilly-sur-Seine (130km)		8 16 40
Pass Troyes (167km) ... ... (Slow approach and 35 km.p.h. through station at Troyes)		8 38 00
Severe slack for permanent way repairs from km 192 to km 196, almost stopping at km 195		
Pass km-post 200		9 2 00
Pass km-post 253		9 30 00
Pass Chaumont (261·5km) at speed		9 35 00
Dead slow at km 294 and prolonged slack until approaching Langres		
Pass Langres (297km)		9 55 30
Pass km-post 300		9 58 00
Slack through Culmont (308km)		
Pass Vesoul (381km)		10 42 00
Pass km-post 410		10 59 00
Pass Lure (411km)		10 59 40
Arr. Belfort (443km)	11 20 00 ...	11 19 30
Dep. Belfort	11 22 00 ...	11 24 30
Dead slow through Petit Croix and for 1km beyond		
Arr. Mulhouse (492km)	11 59 00 ...	11 58 20
Dep. Mulhouse	12 01 00 ...	12 02 40
Dead slow at Rixheim		
Reduced speed through S. Louis (519km) and approaching Bâle		
Arr. Bâle (526km)	12 26 00 ...	12 29 00

Notes	
Inclusive booked time	326 min
Inclusive actual time	327 min 20 sec
Actual time deducting stops ...	318 min 00 sec
Total distance	526km (327 miles)
Average (inclusive) actual speed	96·4 km.p.h. (60 m.p.h.)
Weather fine throughout.	All seats occupied.

The de Dietrich railcar has two four-wheel bogies and is powered by two Saurer oil engines, each of 160 h.p. at 1500 r.p.m. These engines have six cylinders, 134mm by 180mm and each drives a single axle on one of the bogies through Mylius four-speed gearbox. The gear changes are effected electro-pneumatically. This railcar has seats for sixty-one passengers and there is standing room for twenty-six more. The loaded weight of the railcar is 43·1 tons (metric), the overall length of the vehicle being 23·16m. The declared maximum speed is 120 km.p.h. In the de Dietrich railcar one engine is mounted at the forward end, the other engine being mounted at the rear end. The front and rear ends of this car are thus partitioned off to accommodate the engines and to provide space for the drivers' cabs, movement of the railcar being controlled from either end. This type of car was introduced in 1937.

The log printed on p.393 gives particulars of a journey made between Bâle and Paris-Est on the "Autorail Rapide," which leaves Bâle at 7.05 a.m.

The Renault railcar—of a type introduced into service during 1939—is carried on two 4-wheel bogies and powered by two Renault oil engines each of 150 h.p. at 1500 r.p.m. These engines have six cylinders, 140mm by 170mm, and each drives a single axle on one of the bogies through Renault 4-speed gearbox. The gear changes are effected electro-pneumatically. This railcar has seats for seventy-eight passengers and there is standing room for forty-eight more. The loaded weight of the railcar is 40·9 tons, the overall length of the vehicle being 25·93m. The declared maximum speed is 120 km.p.h. In the Renault railcar the two engines are mounted together in the centre of the vehicle, the driver and co-driver being accommodated in a centrally positioned compartment, the upper portion of which is carried through the roof to form a glazed observation turret from which there is clear outlook in all directions. Passenger accommodation is at the ends,

thus providing occupants of the car with unobstructed views forward (or backward) as well as laterally. There are three vestibule entrances on each side of the vehicle with a baggage vestibule beside the enclosed (central) engine compartment.

It will be seen that on neither the east-bound nor west-bound journeys did the observer note a higher speed than 120 km.p.h. (74·5 m.p.h.), and this only occasionally on falling gradients such as the descents from Maison-Rouge, Vauchonvillers and Champagney. The time occupied between kilometre-posts remained steady for long stretches at from 32 sec to 35 sec (113 to 103 km.p.h.). Indeed, the booked time can very easily be kept without reaching higher speeds so long as there are no abnormal

"Autorail Rapide" (Train No. 40).—Bâle to Paris-Est, May 4, 1950.—Renault Railcar No. X7022, S.N.C.F. Log of Run

	Booked h. m. s.	Actual h. m. s.
Depart Bâle	7 05 00 ...	7 05 00
Dead slow into and through St. Louis		
Pass St. Louis		7 12 40
Pass Rixheim		7 24 20
Arr. Mulhouse (after careful approach)	7 29 00 ...	7 29 00
Dep. Mulhouse	7 31 00 ...	7 31 00
Pass Petit Croix		7 52 40
Dead slow for single-line working at Chevremont and protracted permanent way slack (3km) approaching Belfort		
Arr. Belfort	8 8 00 ...	8 04 30
Dep. Belfort	8 10 00 ...	8 09 00
Pass Lure (at 120 km.p.h.) ...		8 27 40
Pass 400 km-post		8 33 30
Pass Vesoul		8 43 15
Pass 350 km-post		8 59 30
Severe permanent way slack west of Hortes, through the tunnel, through Culmont and as far as to km-post 306		
Pass 300 km-post		9 30 30
Pass Langres		9 32 00
Pass Chaumont...		9 50 30
Permanent way slack at km-post 246		
Pass 200 km-post		10 22 40
Severe permanent way slack at km-post 195 due to single-line working as far as km-post 192		
Permanent way slack at St. Juliers and very slow approach to Troyes		
Pass Troyes (at 35 km.p.h.) ...		10 44 20
Pass Romilly-sur-Seine		11 09 15
Pass 100 km-post		11 24 30
Pass Noisy-le-Sec		12 18 30
Arr. Paris (Est)...	12 30 00 ...	12 26 30

NOTES

Inclusive booked time	325 min
Inclusive actual time	321 min 30 sec (dead start to dead stop)
Actual time deducting stop ...	315 min
Total distance	526km (327 miles)
Average (inclusive) actual speed	100 km.p.h. (61 m.p.h.)
Weather fine throughout.	All seats occupied.

delays due to unbooked stops. It is to be noted from the logs printed herewith, that there was no occasion on which either railcar was pulled up to dead stop by adverse signals. West-bound, the distance of 443km, Belfort to Paris, dead start to dead stop, was covered at an average speed of 103 km.p.h. From passing the platform at Troyes to the dead stop at Paris-Est (167km) the average speed was 97·3 km.p.h., notwithstanding which (and after a slow run in from Noisy-le-Sec) the railcar arrived just 3½ min before the booked time of arrival. From the particulars given in the two logs, it will be seen that the journey from Paris to Bâle, including the stops at Belfort and Mulhouse, could be accomplished in five hours, such a performance calling for an inclusive average speed no higher than 105·2 km.p.h., which is well within the capacity of either of the railcars. The extent of the acceleration already afforded by the "Autorail Rapide" is emphasised by comparing the time occupied by representative steam trains. At present (April, 1950) the fastest timing by any steam-hauled train using this route is that given by the "Arlberg Express" (train No. 7). This is allowed 482 min for the 526km Paris-Est to Bâle. There are, however, booked station stoppages at Troyes, Chaumont, Belfort and Mulhouse totalling as much as 45 min. The average speed, inclusive of stops, is thus 65·4 km.p.h. The running time, exclusive of station stops, is 437 min, giving an average speed of just 72 km.p.h.

To recline in the forward seats of the Renault railcar from Bâle to Paris on a fine day is certainly something, and the 325 min passes very rapidly. Among small details one notices the frequent use made by the driver of his musical horn. Indeed, the compassionate Frenchman sounded the horn to warn a dog which was approaching the line near Port-d'Atelier. The driver sits facing the instrument panel, positioned above which is a Flaman speed indicator graduated up to 130 km.p.h. These are side-mounted in the glazed turret. One man drives the railcar right through from Bâle to Paris, the co-driver sharing the lookout. Such control as is necessary in managing the electro-pneumatic gear-changing is by finger-switches and the driver kept the brake handle in his left hand all the time the railcar was in motion. The passage of these fast vehicles over the Paris-Bâle main line must, of course, involve some careful plotting. It has been mentioned that in neither of the journeys detailed on the logs herewith was there any unbooked station stop or any adverse signal except for imposed speed reductions or permanent way repairs. On the west-bound run it was noticed that the 7.30 a.m. steam-hauled express train from Paris to Bâle and beyond passed out of the zone of single-line working between Troyes and Bar-sur-Aube (the west-bound road being in process of re-laying) about one minute before the railcar reached the cross-over points. Indeed, from the front observation windows of the railcar the express could be seen approaching along the single line as the railcar slowed down. Nevertheless, the east-bound train was cleared from the section without there being any need to stop the west-bound railcar.

Looking out through the glazed semi-circular front end of the Renault railcar one realises just what the passenger misses when his vision is limited to glancing in a lateral direction. The entire country is opened up to him as the vehicle traverses Haut-Rhin, Haute Saône and approaches Haute Marne and the famous Plateau de Langres. Unforgettable is the aspect of the ancient fortified city of Langres as the railcar comes within sight of its walls and towers. All too soon we are in Haute Marne, past Chaumont and into the Department of Aube, passing Bricon and the famous district of Clairvaux before slowing down through the quaint town of Troyes with its glorious Gothic cathedral. Skirting Marne at Romilly-sur-Seine we enter Seine et Marne and finally Seine et Oise, the journey having revealed to us the ever changing beauty and eternal interest of Eastern France. Passengers in the front seats of the railcar looking forward and those in the corresponding seats looking backward have a grand opportunity for beholding the country. Indeed, as we sit in either of these compartments and survey the woods and rivers, towns and villages of Eastern France, we become acutely conscious of the fact that the finest outlook positions in a railway train are normally occupied by the locomotive crew. Even in the de Dietrich railcar referred to earlier, passengers are precluded, by the front and rear positions of the engine compartments, from looking at the country except through the side windows.

In the United States—as now in France—the advantage of unobstructed lookout has long been recognised. One has only to travel in the "Skytop" lounge car of the "Hiawatha's" or the "Solarium" lounge car of the "Denver Zephyr" to realise how much can be done, on a railway coach, to disclose the beauty and interest of a journey. We are well-placarded with invitations to see "Beautiful Britain" by railway. Let the railway executive give attention to the problem of producing rolling stock which will assist the passenger to behold this beauty. Why should there not be modern railcars with "Solarium" features on the route (for example) from Glasgow to Oban? Why should the choicest views of Loch Awe, Glen Ogle and Ben Cruachan be monopolised by the smoke belching "Black Stanier" which provides the motive power? Indeed, to look at a steam-hauled passenger train climbing Glen Ogle brings to mind those words which Shakespeare puts into the mouth of Othello:

"O you mortal engines, whose rude throats
The immortal Jove's dread clamours counterfeit,
Farewell!"

It is time this sort of equipment in this sort of territory went the way of the wax candle, the horse-omnibus and the fire-place. With a railcar having the engine unit (or units) centrally mounted and the driver obtaining his outlook (as in the Renault railcar) from a turret in the roof, the passenger will receive altogether better value for his money and the railway executive should benefit both in revenue and reputation. There are already numerous oil-engined railcars on the Western Region of British Railways. Is there any compelling reason why both ends of these railcars should be partitioned-off and notices posted prohibiting passengers from approaching the place whence the best views are obtained? The oil engines are actually below floor level and what is there to exclude a centrally-positioned driver's cabin with lookout turret? If such a railcar can be used between Paris and Bâle, is there any valid reason why similar cars cannot be used on much shorter runs in Wales, the Wye Valley, or in Warwickshire? There is no need to crowd buffets into them. All that they have on the Paris-Bâle railcars is a toilet, though the journey time is 5h 26 min.

Here, surely, is something for our nationalised railways to get busy on and they would certainly have the eager collaboration of builders of vehicles, engines and transmissions. Incidentally, the production of such railcars would be of definite interest to those important industries, a great part of whose business lies in the construction of rolling stock for export. There is no hope for railways if they fail to exercise imagination, and our British Railways are now under a peculiar necessity to employ all that they possess of this incomparable faculty. Well worth their taking to heart are certain words uttered not long since by Mr. W. T. Faricy, President of the Association of American Railways:

"There has never been and never will be a ceiling on improvement in railroad operations and services. Railroad management and railroad employees never rest on past accomplishments; they are never satisfied with what has been done, but instead are always looking for ways and means of doing better."

It should be an encouragement to the railways to remember that there can never be a lack of people who, wishing to see the beautiful territory through which they are passing, will prefer to travel in a railcar on the surface rather than in a mechanised rocket through the air.

Vibrations Due to Blasting and their Effects on Building Structures

By G. MORRIS*

VIBRATIONS of building structures, whatever their source, may cause nuisance or, if of sufficient magnitude, actual damage to the building involved.

Complaints are sometimes received by the users of explosives that damage has been caused by ground vibrations generated by their operations. Such damage is almost invariably slight, and it is usually questionable if the damage was, even to a small extent, due to the effects of nearby blasting operations.

The ground vibrations caused by blasting differ from other types of vibration, in that they are of short duration and usually occur at infrequent intervals; for example, in some quarries major blasting operations are only undertaken at intervals of about a year.

It is well-known to seismologists that lay observers almost invariably overestimate grossly the magnitude of earth vibrations. In addition to this the general public, know-

FIG. 1—PORTABLE VIBROGRAPH

ing that explosives are dangerous if improperly handled, and confusing the commercial use of blasting explosives with the destruction wrought by explosives in warfare, do not realise that in a properly executed blast the effect of the explosive used is closely controlled; they are, probably unconsciously, prone greatly to exaggerate any effects due to ground vibrations arising from this cause.

In blasting operations energy is wasted in three ways, which might be associated with building damage, by the formation of seismic vibrations, by the projection of debris and the production of an air wave, usually known as "air blast." This investigation is concerned only with the first of these phenomena. The projection of debris is so diminished in properly executed blasting operations that it offers no danger, while air blast, so important in military explosives, should be quite insignificant.

The direct attack on the problem of building damage by explosion-generated seismic waves would take the form of blasting operations near typical building structures in which the quantity of explosives was progressively increased until damage of the required type was caused. Opportunities for investigations of this kind are very rare, and it is obvious that a full investigation by such a method would be prohibitively costly.

The alternative method of attack is first to study the vibrations of the ground caused by blasting, and then to develop a method by which the stresses caused by such ground movements in typical building structures can be calculated so that the maximum weight of explosive which can be fired in any specified circumstances without risk of damage to buildings can be ascertained.

PART I.—THE INVESTIGATION OF THE SEISMIC WAVES CAUSED BY BLASTING OPERATIONS

(1) *Vibrographs.*—For an investigation of this kind the recording apparatus has to be simple and portable. It can take the form of a vibrograph to record amplitudes or an accelerometer to record acceleration. Although an accelerometer is much easier to design, the obtaining from its record of the true ground motion is very difficult. Accordingly the author built the apparatus (shown in Figs. 1 and 2), which consists of one or two horizontal pendulums recording a trace photographically on a drum driven by a governed clockwork motor. Details of the pendulum are given in Fig. 3. Experience shows the necessity of calibrating such a vibrograph on a shaking table; the average magnification is thirty-four times.

(2) *Shape of the Vibrograms.*—A number of typical vibrograms recorded near explosions

FIG. 2—VIBROGRAPH PENDULUM

are given in Fig. 4. It is found that the vibrations measured in rock, on overburden, or on the floors of building structures are all of the same general type, which is not greatly influenced by the kind or quantity of explosive, by the distance from the shot or by the geological structure of the site. There is usually a small initial amplitude of greater frequency than the main disturbance. Thereafter the amplitude rises rapidly to its maximum value and then falls off in a roughly exponential manner.

The author's views on the mechanism of generation of elastic waves in the ground by explosives have been published elsewhere.[1] Briefly, the explosion produces a pulse in the ground, which is rapidly degenerated into an elastic pulse by doing work near the borehole. This elastic pulse suffers repeated reflections and refractions at the geological interfaces of the ground, and the vibrogram obtained in field trials is a synthesis of these reflected wavelets.

That the maximum amplitude of a vibrogram is derived from a single pulse is probably responsible for the fact that this quantity is dependent only on the explosive and the distance from the explosion and is independent of the frequency of vibration.

The vibrograms obtained in structures due to blasting differ but little in general type from those measured in the ground, indicating that the structure moves as a whole with the ground on which it stands.

When the building is set in vibration by other than seismic vibration, for example, by

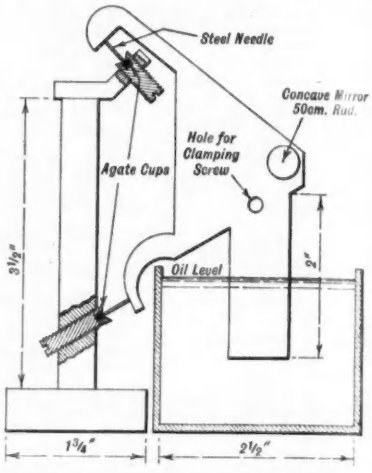

FIG. 3—ARRANGEMENT OF HORIZONTAL PENDULUM

a man jumping, by blows on the walls, by dropping weights on the floor or by the air blast from an imperfectly tamped shot, vibrations of very much higher frequencies, 30 to 200 c/s, are found. These are undoubtedly due to parts of the structure vibrating at their own natural frequency, which is always much greater than that of the structure as a whole. Thoenen and Windes[2] have named this "panel vibration."

Some investigators, notably Rockwell[3], have used vibrations due to what may be termed domestic sources of vibration (e.g., road vehicles, people walking and jumping) as a standard of comparison for blasting vibrations. While such comparisons have a certain value in convincing the layman of the innocuous nature of the vibrations from a properly conducted blast, the greatest care must be taken in using such data to assess the resistance of structures to blasting generated vibrations.

In some publications on this subject[4] attention is paid to the type of wave by which energy is transmitted through the ground. While of great interest in seismology, it is considered that such information is of but little importance in studying the effects of blasting generated earth waves on building structures, which is the principal purpose of an investigation of ground motion comparatively near commercial blasting operations. For this purpose what is required is an empirical method of simply describing the ground motion, preferably in such a way that the results can be conveniently applied to estimate the effect on typical building structures. Such a formula is of great value if it permits an approximate estimate of the ground motion to be made when actual vibration measurements are impracticable.

(3) *Maximum Amplitude of the Vibration.*—One of the three principal parameters

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which define the ground vibration is the maximum value of the amplitude of motion. Since the shape of the recorded vibrograms sometimes leads to uncertainty in the exact position of the zero line to be used in measuring the amplitude, it is the author's practice to take as the maximum amplitude one-half of the distance between the greatest succeeding positive and negative displacements.

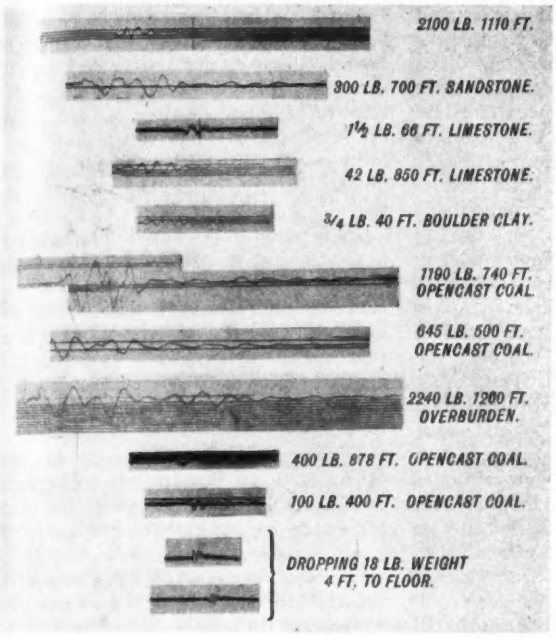
2100 LB. 1110 FT.
300 LB. 700 FT. SANDSTONE.
1½ LB. 66 FT. LIMESTONE.
42 LB. 850 FT. LIMESTONE.
¾ LB. 40 FT. BOULDER CLAY.
1190 LB. 740 FT. OPENCAST COAL.
645 LB. 500 FT. OPENCAST COAL.
2240 LB. 1200 FT. OVERBURDEN.
400 LB. 878 FT. OPENCAST COAL.
100 LB. 400 FT. OPENCAST COAL.
DROPPING 18 LB. WEIGHT 4 FT. TO FLOOR.

FIG. 4—TYPICAL VIBROGRAMS OF GROUND MOTION

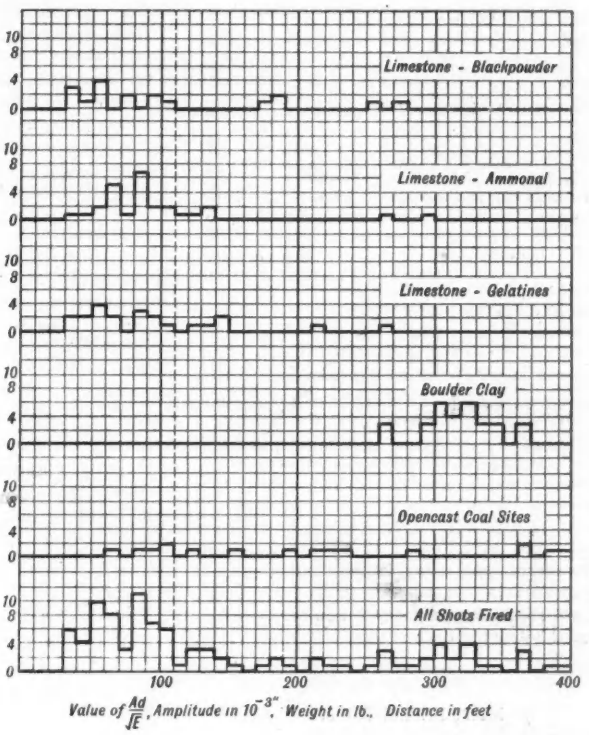

FIG. 5—DISTRIBUTION OF AMPLITUDE CONSTANT

The variation of amplitude of ground motion with a number of factors susceptible to control has been studied and the information obtained is set out below.

(a) *Direction of Motion.*—While the amplitude of motion in the direction of the line from the site of the vibrograph to the point of explosion—that is, of the compressional disturbance—is not equal to that in a direction normal to that line—that is, of the distortional disturbance—the ratio varying with each vibrogram obtained, the two magnitudes are always of the same order. This is confirmed by the experiments of Rockwell[3] and the U.S. Bureau of Mines[2].

(b) *Quantity of Explosive.*—For a given position of shotpoint and vibrograph it would be expected[1] that the ground amplitude would be proportional to the square root of the energy put into the ground, i.e., to the square root of the weight of explosive. The results of some tests by the author are plotted in Fig. 6. Heiland[5] confirms this.

(c) *Type of Explosive.*—But little information appears to have been published on the variation of vibration amplitude with the type of explosive used. Szczepanski[6] states that, as might be expected from energy considerations, the amplitude is proportional to the "power" of the explosive—that is, to the energy released per unit weight.

Experiment shows, however, that this is not so, and that a given weight of explosives produces the same amplitude, to the accuracy of field experiments of this type, in given circumstances, regardless of the type of explosive employed. The range of explosives used varied from blasting black powder, through powder explosives containing nitroglycerine, ammonal and gelatinous explosives to blasting gelatine detonated with its higher velocity of detonation.

This conclusion is supported by an analysis of the work of the U.S. Bureau of Mines[2], by experiments[7] on the efficiency of various explosives in the refraction method of seismic prospecting, and by the experience of quarry operators.

(d) *Degree of Confinement.*—Experiment shows that the intensity of the ground vibration produced by shot firing is not influenced by the degree of confinement of the charge—that is, of the quantity of tamping used.

(e) *Balance of the Shot.*—A shot is said to be "balanced" when the quantity of explosive is correctly selected to do the work required of it—that is, the shot is neither under nor overcharged. Small variations in the quantity of explosive on either side of balance do not appear to affect the amplitude of the vibration produced. Thoenen

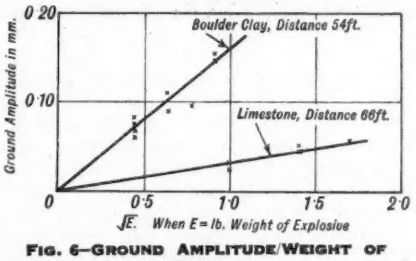

FIG. 6—GROUND AMPLITUDE/WEIGHT OF CHARGE

and Windes[2] have shown that a shot so badly undercharged that the rock is not broken generates a greater amplitude of ground motion than a balanced shot, while Schulz and Rossiger[8] found that greater amplitudes were generated by overcharged shots. It appears, therefore, that proper balance of the explosive charges reduces the ground vibration generated to a minimum.

(f) *Simultaneous Firing.*—When several shots are fired instantaneously the result is the same as if that weight of explosive had been fired in a single hole, provided that the charges are close enough together. When delays of about one second are used the recorded amplitude is that of so many single blasts. Recent tests show that with short intervals of the order of 25 milliseconds a notable reduction in ground vibration is obtained.[9]

(g) *Effect of Distance and Nature of the Ground.*—Theoretically it would be expected that the amplitude of ground vibration would be inversely proportional to the distance from the shotpoint. Unfortunately, this quantity is different for each component of the surface vibration since each component has come from the shotpoint to the vibrograph along a different path. It is nevertheless found to be a very useful empirical relation that the amplitude of the ground vibration is inversely proportional to the distance from the shotpoint to the vibrograph measured along the surface. The quantity $Ad/\sqrt{E}$ has been calculated for a large number of tests made by the author, and is shown in Fig. 5. It will be seen that the quantity is variable, ranging from 30 to over 400. The average figure is 110 where A is the amplitude in thousandths of an inch, d is the distance in feet and E is the weight of explosive in pounds. Data published by Rockwell give a mean value of 140 in the same units and analysis of the Bureau of Mines' figures gives 115.

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(*To be continued*)

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PRINTING DIFFICULTIES

We regret that owing to the continuance of the dispute in the printing trade this issue has to be an "emergency" number heavily reduced below the normal size.

MAN MADE RAIN

DURING the last few years many experiments have been carried out, particularly in the U.S.A. and the Dominions, to determine whether, and if so, to what extent, it is possible by human effort to control rainfall. The earlier experimenters favoured the use of crushed "dry ice" as the best mode of attack on the problem, but later workers have met with not a little success in their use of quite small amounts of silver iodide. Either, it appears, can be used for the "seeding"—as it is called—of selected cloud formations, and for doing so an aircraft has usually been chosen as the appropriate carrier. But it fortunately happens that although silver iodide can be quite readily seeded in this way, this material lends itself to the much less costly procedure of merely burning the substance at ground level and letting the fumes rise in the heated air until they reach the cloud formations selected as suitable. The use of a silver salt may sound expensive, but the quantities required are surprisingly small, partly, no doubt, because the desired effect, once it starts, takes the form of a chain reaction, such as occurs in any spreading fire, or in the well-known nuclear fission of uranium. If further experiment reveals that the method is really practicable and fully controllable, the scope of the work of engineers is likely to be further widened. For those professionally interested in rain-making will no doubt be irrigation engineers.

A very interesting account was given recently of the results obtained in a number of tests in the U.S.A. by Dr. Irving Langmuir, of the General Electric Research Laboratories, when addressing the American Meteorological Society. It is obvious that in any such tests there is bound to exist some uncertainty whether any rain which may follow the cloud seeding would not have fallen in any event; but when enough experiments have been made a probability factor can be assessed which will serve as a useful guide to judgment. One of the many conveniences of radar is that it enables the presence of raindrops in a cloud to be detected from many miles away, so providing a useful means of watching what happens and of controlling the amount and extent of the seeding required for the job in hand. Even so, there may for long remain critical minds which are not entirely convinced and find it hard to share the optimism of others (a doubt amusingly illustrated in a recent U.S. weekly in which two parsons gazing through a church window at the heavy rain outside ask one another, "Is it theirs or ours?") But it is clear from Dr. Langmuir's address that he is himself in no doubt not only of the possibility of effective human action in rainfall control, but of its immense potential importance. If he is right, not only can rainfall in some areas be redistributed, but climate can be affected, and hurricanes halted in their destructive approach to land areas. Moreover, the cost of doing so need not be at all considerable. Dr. Langmuir calculates that to obtain a 30 per cent chance of rain per day within a given area (actually in New Mexico), the cost of the silver iodide may be no more than a dollar or so for each 4000 square miles, so that if similar conditions prevailed over the whole of the United States the cost per day to double the rainfall would only be of the order of 200 dollars. It will be agreed that there are other than technical and financial considerations which need to be taken into account. There are legal problems, such as the responsibility attaching to any diversion of the customary rainfall from one district to another, or to the damage that might be done by sudden excessive rainfall over an area, or State, that had not asked for anything of the sort. Some mutterings as to intended legal action have already been heard in the U.S.A. There might even arise international complications—to a "cold war" there might be added a "wet" one! The purely legal complexities should, however, not prove hard to solve when they are confined within a single State, since existing laws relating to the diversion of rivers and streams could probably be fairly easily extended to cover this new human activity, or else be amended until they did do so.

If the path can be cleared of technical and legal obstacles, it does not seem that finance can stand in the way; the cost of the raw material is slight and its distribution, even by aircraft, a trifling burden compared with the enormously valuable benefits which might be brought to agriculture. No doubt most rain at present falls into the sea, but an excess far beyond the local needs concentrates in mountainous areas, and there cannot be doubt that its better distribution would enable much more of the earth's surface to be put into cultivation. Time alone will show how far these benefits can be realised. The one sure thing seems to be that if this new experimental work succeeds it will present the double prospect of conferring great human benefit combined with very little disadvantage at all to anyone—which is more than can be said of all new discoveries.

Literature

Development of Aircraft Engines, by ROBERT SCLAIFER, *and of Aviation Fuels*, by S. D. HERON. Two Studies of relations between Government and Industry. Harvard School of Business Administration, Boston. 5·75 dollars.

THIS is an important book and is excellently written. A striking feature is its dual aspect for there is contained in this single volume not only an intimate and absorbingly interesting account of the ways in which recent developments, including much that is new or unfamiliar, in aircraft engines and their fuels came to birth, but it discusses also the conditions in which this work has been carried out in the leading countries of the world. In the years covered the relations between Government and industry have changed so rapidly in this particular field, as in so many others, that an up-to-date survey is particularly welcome. Such a study has an important bearing on the choice of the methods of investigation likely to be found most useful in many fundamental engineering investigations in the strange new world in which we now live.

Despite the book's modest short title, it is clear from its "Foreword" that a larger purpose was in mind when the Harvard Business School determined to initiate an inquiry of a semi-political character and selected the field of aviation as a suitable first objective. It had originally contemplated the subject of aircraft as a whole, but for practical reasons decided to limit it, in the first instance at least, to a single major "component," viz., the aircraft engine and its fuel.

It was no doubt advisable, in view of the vastness of the field, to employ a sampling process of this kind, though to some readers it may seem odd that the sample should not have included the whole of aviation instead of only a part of it, and that not the most important part. Reflection, however, supports this decision for, in the choice between State-directed methods and those of private enterprise, regard needs to be taken of the recent growth in the size and speed of aircraft, which has been so rapid and so considerable as to require the use of such large and powerful wind tunnels, costing many hundreds of thousands of pounds, that it is highly uneconomic for individual manufacturers so to equip themselves; and through this open door the State planner, welcome or not, naturally enters. Moreover, once a major problem has been remitted to a State research establishment it is but natural for the minor ones which develop from it to be taken over by the same organisation. This is not a situation nearly so likely to occur in other industries and it follows that aircraft development as a whole would hardly provide a representative sample. The smaller field of aero-engine research is free from this particular difficulty; it may need wind tunnel assistance, on turbine

blades, for example, but not on the massive scale of that needed for aircraft themselves. It is feasible therefore that the methods employed in research and development work on the engine should be capable of being more evenly balanced between State and private enterprise.

As it happens, neither the Advisory Committee for Aeronautics in this country nor the National Advisory Committee for Aeronautics in U.S.A. took nearly so active a share during the inter-war years in the development of the aero-engine as in the rest of the aircraft. Indeed, if the record given in this book is accepted, their participation was far from being as vigorously sponsored as might have been expected, especially during the infancy of the turbo-jet types.

On the comparative merits of private enterprise and State organisation in general, strong opinions are held by important sections of the public. But in the field of fundamental research, whether scientific or technical, both would seem to have a legitimate sphere, even if the task of establishing any logical boundary between them may be hard. In the U.S.A. one sees what seems to us the odd situation of certain vital research problems—even such secret ones as those on atomic energy—being remitted by the Government to the universities on a repayment basis. This is rare here and we are glad that that should be so. In this country it is preferred that university researches should aim at the acquisition of fundamental knowledge and its subsequent publication—avoiding as far as possible the undertaking of secret research work, whether for official or private organisations. Either procedure can, of course, complicate the drawing of defensible boundaries between the activities of Governmental and private research staffs, but need not make it impossible.

This book suggests that the American Service Departments would profit by following the British example of having military officers participating only in the setting of objectives, leaving the highest engineering posts in the hands of civilians; it points out that when a British official promises support to a project the firm can rely on that undertaking, whereas "the corresponding American official could not even be sure that he would be in charge of the project a single year later." The organisation in Germany had some features very similar to those in Britain and U.S.A., but it seems that, for various reasons, co-operation between the firms engaged in aero-engine manufacture was much less common, especially where the new turbine types were concerned. Moreover, Germany suffered grievously through non-technically-informed direction from above. There was, it seems, a serious shortage of trained personnel for engine development by about the middle of 1940, but the orders given by the General Staff were that development must not interfere with production, since the war would be short, and that what was wanted was the immediate production of existing models. Professor Sclaifer does not hesitate to state that Milch, when Goering's deputy, was completely unaffected by the technical arguments offered by his engineers. Hitler himself is cited as the direct cause of the loss of six vital months in the appearance of the jet propelled "Me262," which, though designed as a fighter, should, he insisted (until he changed his mind) be converted into a bomber to use against England. Germany, by this decision, lost much of the lead in jet-fighter production she might otherwise have had during the critical months of 1945.

The last 100 pages of the book are concerned with the development of aviation fuels. The author, Mr. S. D. Heron, frankly points out that what he writes is less the result of research inquiry than the fruit of personal recollection and that any "censorship" by the Harvard Business School was strictly confined to the power of declining to publish! That we are glad to see did not happen, for Mr. Heron's record of events as he remembers them will be read with much interest by chemists and chemical engineers. It is not claimed, however, that the important consequences of fuel improvement in the performance of piston engines in the past are likely to be repeated with the turbine; indeed, Mr. Heron expresses the opinion that "most of the possible advances with hydrocarbons as an aircraft fuel appear to have been performed and revolutions due to fuel are likely to have to depend upon atomic energy or some other source almost entirely foreign to hydrocarbons." If this is so it is not to be expected that much useful guidance as to future action can be derived from this story of the development of fuels for piston engines, however interesting from an historical point of view it certainly is.

How then should the industrialist make his choice between State organisation and private enterprise for the necessary work of research and development? As regards development the answer can hardly be in doubt, since experience in general—including that surveyed in this book—shows that the enterprise of the private manufacturer will always lead that of any bureaucratic organisation. For research investigations the choice is less simple; experience, however, shows that the best work is done where the conditions come closest to those prevailing in universities. In the achievement of these favourable circumstances sometimes the State organisation will lead and sometimes private enterprise. The one safe choice is to send the work to the best man on the subject, wherever he is to be found. In successful research it is the very few who count.

Acoustic Measurements. By LEON L. BERANEK. London: Chapman and Hall, Ltd., 37, Essex Street. Price 56s.

THAT in a book of 900 well-filled pages (first published in U.S.) devoted to acoustical measurements the measurement of sound intensity should only fill one page of text may seem surprising, since intensity is generally regarded as one of the basic physical quantities in acoustics. The explanation resides simply in the definition given to the term intensity. The introductory chapter contains an excellent glossary of definitions of terms used in the book, and there is evidence that the author has consulted the British as well as the American Standards publications. He does not, however, draw attention to a difference between them in the definition of intensity. The two are the same for free progressive waves, but for other (and much more common) forms of sound field the American definition retains the concept of energy flow (involving direction as well as magnitude), while according to the British definition intensity is simply a function of sound pressure. Evidently the concept of energy flow has less practical significance in acoustics than the very frequent usage of the term intensity in American literature would seem to indicate.

The book covers a wide range of acoustic and electro-acoustic measurements, both objective and subjective methods of testing being well represented; it contains numerous references to original work, but, as far as European practice is concerned, the sources of references used are somewhat deficient. The author's difficulty in this respect is no doubt largely due to the absence in Europe of a journal devoted to acoustics which has the standing of the J.A.S.A.

In the chapter concerned with primary calibrations of microphones the Rayleigh disc is treated as a means for the measurement of particle velocity (which, of course, it is), but there is no mention of methods of its application to the calibration of microphones. Yet the use of the Rayleigh disc at frequencies of resonance in a tube to obtain pressure calibrations has been a regular practice in this country for nearly a quarter of a century, and this method is at least as accurate as and simpler than the reciprocity technique, which the author appears to regard as the only one now worthy of serious attention. The compensator principle and its stages of evolution (in Germany) up to the electrostatic actuator deserve mention in a work of this magnitude; older techniques, if based on sound principles, can have useful applications in particular cases even after their original forms have been generally discarded.

Another omission which is perhaps of more importance to European than to American readers relates to methods of rating telephone systems by articulation (or by immediate appreciation) tests. In particular, a method is now being studied internationally for obtaining, from articulation testing applied in a certain way, ratings which can serve as a basis for a revised plan for telephone transmission in Europe.

The scope of the book can be indicated briefly as covering methods and apparatus for electro-acoustic measurements of the type with which laboratory investigations are concerned, with greater emphasis on the more recent and more complex devices. The book is not concerned with routine measurements applied in the field, except that they are derived from laboratory methods. Special sections are not devoted to ultrasonics and underwater sound, but these subjects are not entirely neglected. Some of the more complex techniques, e.g., of reciprocity and the calibration of sound analysers, are treated very fully. While the help given is invaluable the choice of method best suited to the circumstances remains the experimenter's responsibility and first principles are his surest guide. An attractive feature of the book is the fullness and clarity of the explanatory matter associated with each of the very numerous illustrations.

The author's own contributions to acoustics are substantial, particularly in measurements of acoustical impedance and of acoustic properties of materials; his comments are based on wide experience and are always interesting. His book will be kept handy for reference in laboratories where acoustical investigations are undertaken.

BOOKS RECEIVED

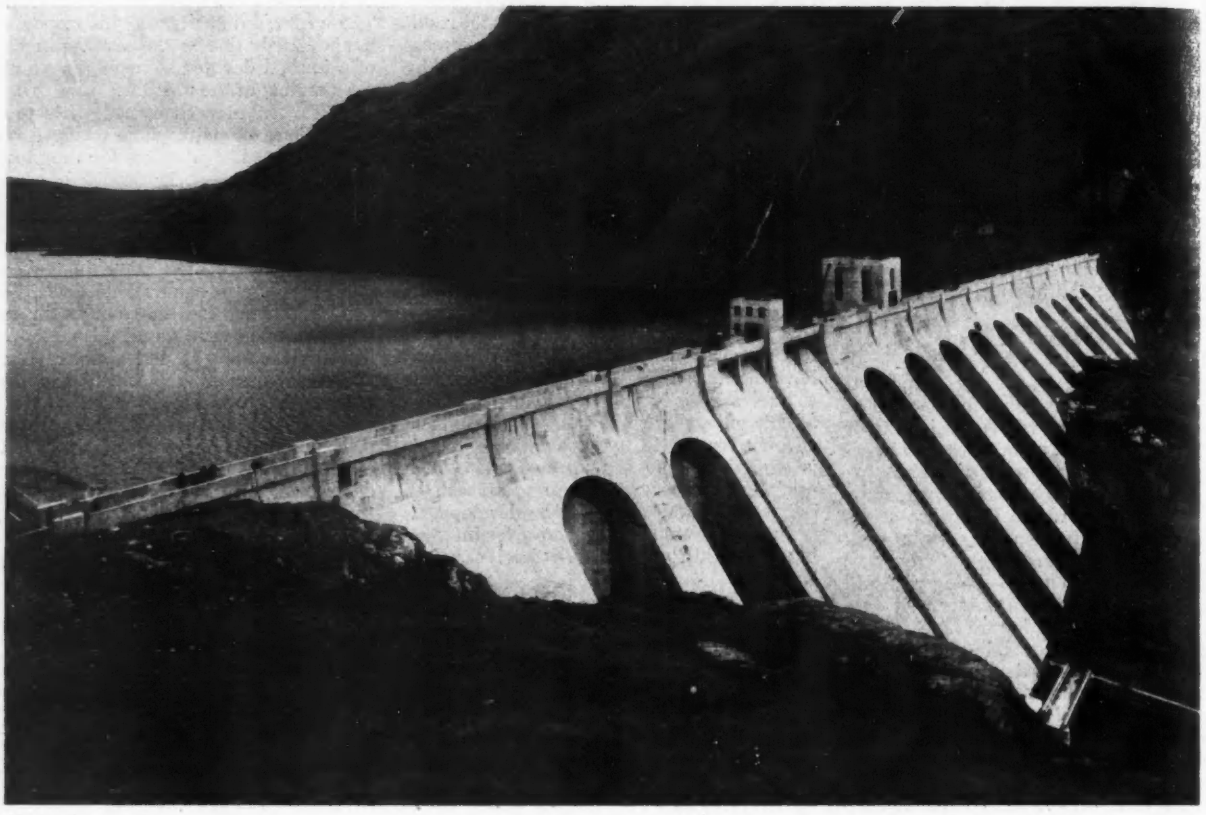
Support of the Roof at the Coal Face. London: National Coal Board, Hobart House, Grosvenor Place, S.W.1.

Quakers in Science and Industry. By Arthur Raistrick. London: The Bannisdale Press, 46–47, Chancery Lane, W.C.2. Price 21s.

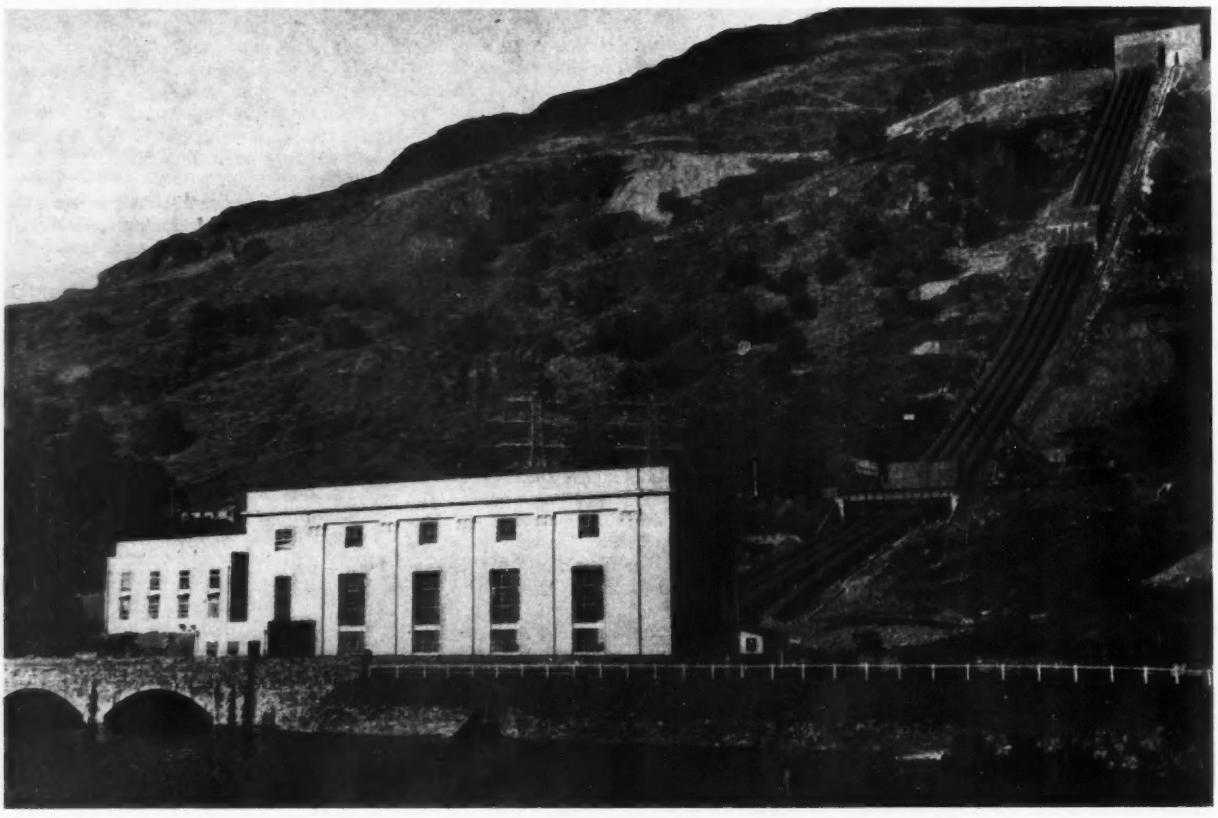
Metallurgical Applications of the Electron Microscope. London: The Institute of Metals, 4, Grosvenor Gardens, S.W.1. Price 21s.

"HEAT PUMPS AND THERMAL COMPRESSORS."—In our review of this book by S. J. Davies in our issue of October 13th the price of the book was incorrectly printed as 8s. The correct price is 9s.

OPENING OF THE LOCH SLOY SCHEME

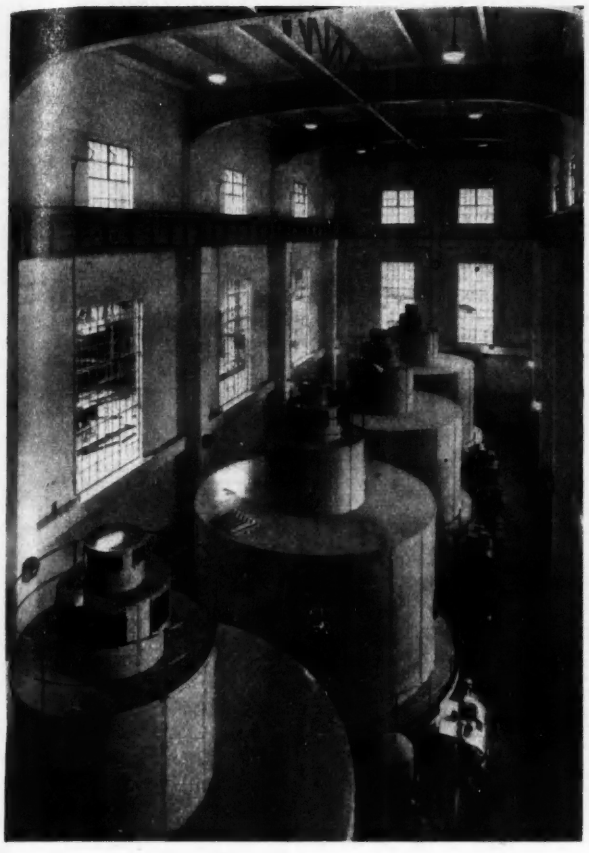


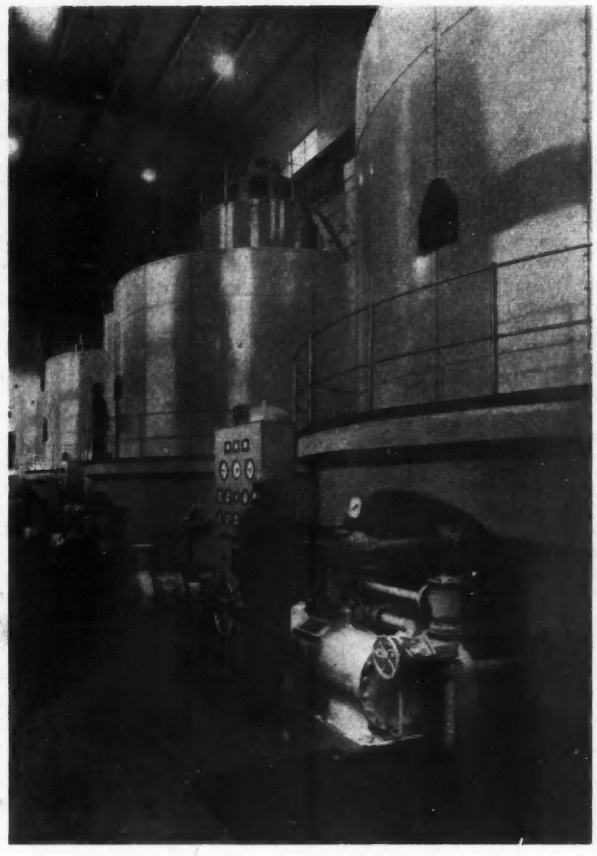
LOCH SLOY DAM



POWER STATION, PIPE LINE AND VALVE HOUSE

TURBO-ALTERNATOR ROOM, LOCH SLOY POWER STATION





Opening of the Loch Sloy Scheme

On Wednesday, October 18th, the Loch Sloy scheme of the North of Scotland Hydro-Electric Board was officially opened by Her Majesty the Queen, in the presence of some 2000 people. During her address, the Queen remarked that she was sure that everyone would join with her in expressing the warmest admiration for those whose vision, tenacity and technical skill had been welded together in facing and conquering so formidable a task. She continued by remarking on the benefits which hydro-electric power would bring, particularly to the rural areas, a point which was also developed by Mr. Thomas Johnston, Chairman of the Board, in his speech which opened the proceedings.

Although the electricity production of the Board's schemes in the Tummel-Garry and the Mullardoch-Fasnakyle-Affric regions will be substantially larger than that at Loch Sloy, physically the Loch Sloy scheme is the largest. It has only one dam, as against two or three in the case of the other schemes, and since it is designed for peak load operation, the installed capacity of the power station is relatively large.

A full description of the scheme was given in our issues of July 21st and 28th and August 4th of this year (pages 57, 87 and 115). It is a high head development (910ft maximum) consisting of a gravity buttress dam, which is shown in our illustration opposite, across the south eastern end of Loch Sloy, from which a main tunnel nearly 2 miles long leads to the valve house, pipe-line and power station shown in our second illustration. There are four main Francis turbine sets, each of 32·5MW, in the power station, whose tail race leads into Loch Lomond. The normal production of the scheme will be about 120 million units a year. Work on the scheme is now completed except for the construction of some of the collecting aqueducts, which will not be finished until 1952.

Completion of the House of Commons

The new House of Commons Chamber at Westminster has now been completed, and was handed over by the Ministry of Works for occupation on October 26th. The new House has been erected on the site of its predecessor, which was destroyed in 1941, at an estimated cost of £1,750,000. It is built in the Gothic style, the dimensions and general layout of the debating chamber being the same as those of the old House. Greatly improved facilities have been provided however in the galleries and rooms surrounding the Chamber, and much ingenuity has been shown in fulfilling the numerous demands for better accommodation and services within the limited space available. Structurally the building consists of a steel frame with reinforced concrete slab or hollow tile floors, the r.c. footings of the stanchions being formed within the 5ft thickness of the old lime concrete raft covering the area.

There are eight air conditioning plants within the building, two of them serving the Chamber, and the remainder serving various other floors and offices. The air supply to any part of the building can be adjusted to maintain any desired temperature and relative humidity. Occupancy of the Chamber may vary rapidly and the operator in charge has full control of the plants and can pre-set their operation with complete flexibility and thus anticipate the effects of changes. There are various automatic control devices and a complete system of distant reading thermometers and hygrometers to enable the operator to check conditions throughout the building, and he can also view the chamber through a periscope. On a division, air is diverted from the Chamber to the Lobbies.

Lighting throughout the building is generally by fluorescent tubes. In the Chamber there are 150 glass laylight panels each with its own cold cathode fluorescent tube, and the brightness can be maintained at any desired level. There are in all fourteen different electrical systems in the building. One of the most interesting is the annunciator system by which a message is transmitted from a central operating room to receiving instruments situated about the building, where it appears in a window in the case of each instrument until displaced by a further message. Sound amplification within the Chamber is controlled by an operator in a small cubicle at the south end, who selects the appropriate microphone and controls the volume of sound. The natural speech is reinforced by loud speakers set in the seating, which are regulated to avoid any clash with speech heard directly.

The consulting engineers for the structural work and air conditioning installation were Oscar Faber and Partners and the architect for the new House was Sir Giles Gilbert Scott.

Strip Rolling Mill.—In the description of a strip rolling mill built by Sir James Farmer Norton and Co., Ltd., which appeared in The Engineer of October 6, 1950, it was stated in error that the plant was designed to roll strip down to thicknesses from 0·140 to 0·105in. This thickness range should have been given as 0·140 to 0·015in.

French steel production plans for 1952, excluding the Saar, include 12·5 million tons of ingot steel. There will also be an increase to 4 million tons in the production of Martin steel. Normal production capacity this year is about 11 million tons of ingot steel, so increased production will depend upon the modernisation of plant. Particular attention is being paid to finished steel products and modernisation in this direction is being pushed ahead.

The Three-Quarter Radius Pitot Tube Flow Meter

By J. H. PRESTON, M.A., Ph.D., A.F.R.Ae.S.*

FLOW meters for measuring large rates of flow of air in pipes usually take one of three forms, i.e., the plate orifice, the venturi and the central pitot tube.[1] The plate orifice, under certain conditions, has a nearly constant calibration coefficient, but it suffers from the disadvantage of a large loss of head when the speed of flow is large. The venturi has a low loss, is less compact and more difficult to manufacture, and its calibration coefficient may be affected by flow conditions upstream, arising from proximity to a bend or a sudden change of section. It thus needs to be calibrated in position; consequently a considerable extension of the pipe-line is necessary. The central pitot is compact and has no loss, but it is not reliable where asymmetry exists in the velocity distribution across different diameters of the pipe, owing to the fact that a change of velocity on the axis need not necessarily indicate a change of flux. Thus a considerable length of pipe is necessary for the flow to become uniform, and even then the ratio of the mean velocity to the velocity on the axis is a function of the Reynolds number. All of these meters are usually calibrated for large volume rates of flow by means of a pitot tube traversed across a section of the pipe where conditions are uniform.

Recent boundary-layer control experiments at the N.P.L. required the metering of the airflow with the minimum of loss and extension of the duct system. This ruled out the plate orifice and the venturi. The flow was therefore metered by a central pitot in some cases, but the accuracy of the measurements was poor owing to its proximity to a bend or change of duct section. Another method employed was the use of a movable comb of fixed pitot tubes in a duct of rectangular cross section. This was more accurate, but was much more tedious than the use of the single pitot tube, since the total head of each tube had to be recorded and considerable calculation was necessary before the flux could be deduced. This was a distinct disadvantage since the experiments were such that an immediate knowledge of the flux was highly desirable.

In conjunction with other schemes, the idea of using a number of equally spaced pitot tubes at the same radius in a circular pipe was examined and found to be very attractive. Compactness and low loss were inherent in the scheme. Asymmetry in the flow could be detected by examining the readings of the individual tubes, whilst their mean, minus the mean static pressure, could be related to the quantity flow by calibration. The radial position r of the tubes was to be such that the contribution $2\pi r.dr.u$ to the total flux of an elementary annulus dr was near the maximum, thus giving the best sensitivity. Subsequent examination of the problem, using an empirical velocity distribution of the form

$$\frac{u}{U_1}=\left(\frac{y}{R}\right)^{1/m}$$

where U_1 is the velocity on the axis, R is the pipe radius and y is the distance from the wall and $m \doteqdot 7$, showed that if the pitot tubes were located at $r/R=3/4$, then a calibration constant $\doteqdot 1{\cdot}0$ could be obtained for a wide range of m and further that this position was reasonably close to the maximum value of ur.

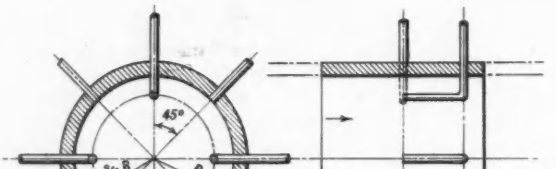


FIG. 1—THE THREE-QUARTER RADIUS FLOW METER

A trial instrument (Fig. 1) was made up using four pitot tubes and four equally spaced static holes in the wall of a 2in pipe. A description of the instrument and of its behaviour is given in the Appendix.

Notation:

R=radius of pipe,
U_1=velocity on axis,
r=any radius,
y=distance from wall$=R-r$,
u=axial velocity at y or r,
w=circumferential or swirl velocity,
$\bar{r}=r/R$,
$\bar{y}=y/R$,
$\bar{u}=u/U_1$,
U_m=mean velocity,
Q=quantity per second,
Q^1=quantity per second based on pitot reading at $\bar{r}=3/4$,
$1/m$=index in $\bar{u}=\bar{y}^{1/m}$,
$\bar{y}_1$=value of $\bar{y}$ at which $u=U_m$,
$\bar{y}_2$=value of $\bar{y}$ at which $u.r$ is a maximum,
H=total head,
p=static pressure.

THEORY

The formula

$$\bar{u}=\bar{y}^{1/m}=(1-\bar{r})^{1/m} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

has frequently been used to approximate to the experimental velocity distribution in a pipe. For medium Reynolds numbers $m=7$ has given good results and at higher Reynolds numbers agreement can be maintained by increasing m to 8, 9, &c.,

The quantity per sec. Q is given by

$$Q=\int_0^R u \,.\, 2\pi \,.\, r \,.\, dr$$

or

$$\frac{Q}{\pi R^2 U_1}=2\int_0^1 \bar{u} \,.\, \bar{r}d\bar{r}=2\int_0^1 \bar{u}(1-\bar{y})d\bar{y} \quad . \quad (2)$$

Substituting from (1)

$$\frac{Q}{\pi R^2 U_1}=2\int_0^1 (\bar{y}^{1/m}-\bar{y}^{1+1/m})d\bar{y}=\frac{2m^2}{(m+1)(2m+1)} \quad . \quad . \quad . \quad (3)$$

Writing

$$Q=\pi \,.\, R^2 \,.\, U_m,$$

then

$$\frac{U_m}{U_1}=\frac{2m^2}{(m+1)(2m+1)} \quad . \quad . \quad . \quad (4)$$

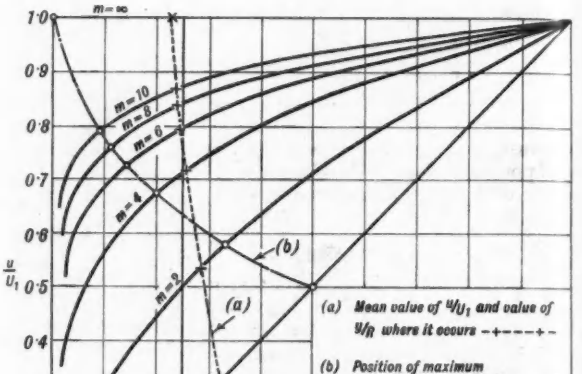


FIG. 2—PIPE VELOCITY DISTRIBUTIONS $U/U_1=(Y/R)^{1/M}$

The distance from the wall at which $u=U_m$ is given by

$$\bar{y}_1=\left(\frac{U_m}{U_1}\right)^m=\left\{\frac{2m^2}{(m+1)(2m+1)}\right\}^m \quad . \quad . \quad (5)$$

$\bar{y}_1$ is tabulated in Table I for various values of m. It is remarkable that for $2<m<10$, $0{\cdot}284>\bar{y}_1>0{\cdot}2375$. The velocity distributions (equation (1)) are shown on Fig. 2 and the position and value of the mean velocity are also shown. This suggests locating the pitot tubes at

$$\bar{r}=\frac{r}{R}=\frac{3}{4}.$$

If we define

$$Q^1=\pi R^2 U_1(\bar{u})_{\bar{r}=3/4} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

then

$$\frac{Q^1}{Q}=\left(\frac{1}{4}\right)^{1/m} \,.\, \frac{(m+1)(2m+1)}{2m^2} \quad . \quad . \quad (7)$$

Q^1/Q is shown in Table I, where for

$$2<m<10,$$
$$0{\cdot}938<Q^1/Q<1{\cdot}005$$

and for

$$4<m<10,$$
$$0{\cdot}995<Q^1/Q<1{\cdot}005.$$

Thus for velocity distributions lying in this latter range of m, the error in quantity, due to taking the velocity at $r/R=3/4$ as the mean velocity is within $\pm\frac{1}{2}$ per cent of the correct value. Hence changes of velocity distribution due to change of Reynolds number are unlikely to affect the calibration. Also

* Cambridge University Aeronautics Laboratory.

effects of asymmetry in the velocity distribution can be taken account of by reading each tube and static point separately and then deducing the velocity at each pitot mouth and taking a mean. If the asymmetry is slight, then the mean total head minus the mean static pressure should suffice.

The greatest contribution to the flux occurs where $u.r$ is a maximum (see equation 2), i.e., when $(\bar{y}^{1/m}-\bar{y}^{1+1/m})$ is a maximum. This occurs at $\bar{y}=\bar{y}_2$ where

$$\bar{y}_2=\frac{1}{m+1} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

This is tabulated in Table I and shown on Fig. 2. For $m=3$ it is $R/4$ from the wall and for $m=7$ it is at $R/8$ from the wall. Thus in practice the pitot tube at $3R/4$ from the axis will be inboard of the most sensitive position, but obviously it is a great improvement over the axial position. The $3R/4$ position has the advantage of simple specification and a calibration coefficient $\div 1\cdot 0$.

TABLE I.—*Instrument Characteristics*

m	1	2	3	4	5	6	7	8	9	10
$\bar{y}_1$	0·333	0·284	0·2655	0·256	0·2495	0·245	0·242	0·240	0·2385	0·2375
Q^1/Q	0·750	0·938	0·980	0·995	1·000	1·003	1·004	1·005	1·005	1·005
$\bar{y}_2$	0·5	0·333	0·250	0·200	0·167	0·143	0·125	0·111	0·100	0·091

FORM OF THE INSTRUMENT

In its simplest form (Fig. 1) the instrument need consist only of an accurately turned length of tube of suitable internal diameter, to avoid too high or too low a speed, with four fine pitot tubes at 90 deg. intervals on the $3R/4$ radius, and four static holes at the wall also 90 deg. apart. The static holes should be at least 10 pitot tube diameters upstream of the radial part of the pitot tube, and should be in line with the pitot tube mouths, but should lie on diameters offset 45 deg. from those on which the pitot tubes lie to avoid interference.† The sketch (Fig. 1) makes this clear. The unit should extend about half a pipe diameter ahead and behind the static holes and should fit smoothly in the pipe-line without leaks. The instrument can be calibrated by carrying out a pitot traverse of a section of pipe some distance behind the unit.

A more elaborate form would be one in which each of the four pitot tubes could be traversed by a micrometer from the wall of the pipe to beyond the axis of the pipe. Such an instrument could be accurately calibrated in situ and if necessary the pitot tubes could be set at such a radius that the calibration constant was unity.

A variation of this would be to have only one of the pitot tubes with a micrometer attachment and to have the unit capable of being rotated and set at 90 deg., 180 deg. and 270 deg. to its original position.

Some experiments with a trial instrument are described in the Appendix.

RANGE OF INSTRUMENT

Speed.—The instrument is especially suitable for high-speed flows because of its negligible loss and the fact that standard corrections for the effect of compressibility can be applied above 200ft per second. At low speeds a sensitive gauge will be required and it would seem that a mean speed of about 40ft per second is the lowest that is desirable for good accuracy if a Chattock gauge or inclined manometer is used.

Size.—There is no upper limit to the pipe diameter ($2R$) provided the pitot tubes are of such a size as to ensure adequate rigidity and yet are not too large to affect the accuracy of the readings close to the wall. The lower limit will probably be set at a pipe diameter of $\frac{1}{2}$in using the finest hypodermic tubing for the pitot tubes.

Quantity Flow.—From the foregoing is appears that there should be no practical upper limit to the quantity per second, but there is a lower limit given by the product of a mean speed of 40ft per second into the area of a $\frac{1}{2}$in diameter pipe, which gives a lower limit of about 3 cubic feet per minute. With a flow as low as this it would probably be wise to check the calibration by a water displacement method.

FACTORS AFFECTING ACCURACY

Asymmetry in the Distribution of Total Head and Static Pressure.—The velocity at any point is given by $\sqrt{2(H-p)/\rho}$ where H is the total head and p is the static pressure. Unless the static pressure at the pitot position is actually measured we must assume that it is the mean of that recorded at the two adjacent static holes. The total heads can be measured separately and hence the velocity at the four pitot tube positions can be obtained and meaned. This should give good accuracy for the estimate of quantity. If the asymmetry in total head is not marked, then the mean of the four total heads minus the mean of the four static pressures at the wall obtained as a single reading should suffice. In the case of marked asymmetry arising from proximity to a bend or sudden change of section, it will probably pay to insert a fine honeycomb element behind this, in order to smooth out the disturbance.

Swirl.—The total head reading of pitot tubes is unaffected by inclination to the direction of the stream lines, provided this is less than about 20 deg.; hence assuming that the true static pressure is known, then it follows that the dynamic head will be that of the resultant velocity $=\sqrt{u^2+w^2}$ and not that for u the axial component. However, if $w/u<0\cdot 1$, the error is small. When swirl is present it is possible for serious variations of static pressure to occur across the pipe. The "three-quarter radius" position is near the wall and so the wall static pressures may be sufficiently accurate. It is important that the calibration should be made where the swirl is small, if the distribution of static pressure across the pipe is not measured. Swirl and asymmetry will probably be present together, close behind a bend, and hence a fine honeycomb element should be placed there to remove it.

Calibration.—The calibration, in general, will be made by a traversing pitot tube, which should start from the wall. Care must be taken that the pitot tube mouth is just in contact there. The pitot tube should be traversed across two diameters at right angles for accuracy, and the traverse should be made where the swirl is small. Corrections should be applied to readings near the wall for the effective displacement of the pitot tube mouth.[2] Readings for which $\frac{ud}{\nu}<30$, where d is the diameter of the pitot tube, are liable to errors.[3] Compressibility corrections must be applied above 200ft per second.

Setting of Pitot Tubes and Finish of Static Holes.—Small errors in the location of the pitot tube mouths at three-quarter radius will not result in serious errors in quantity per second. This can be seen from reference to Table I or Fig. 2. Precision alignment of the pitot tubes with the pipe axis is not required, though it is as well to aim at it. Static holes should be as small as possible consistent with freedom of movement of the manometer liquid. They should be carefully finished to avoid burrs.

Clogging of Pitot Tubes and Static Tubes.—The tubes should be made of nickel or stainless steel to prevent corrosion. Care must be taken to see that moisture does not condense in tubes of small diameter. This is a frequent and unsuspected source of trouble; it is readily cleared by applying gentle heat.

Dust or soot laden air streams may be expected to choke fine pitot tubes ultimately, and so may prevent the use of the instrument in its present form. However, it may be feasible to point the tubes downstream and to calibrate them for this arrangement.

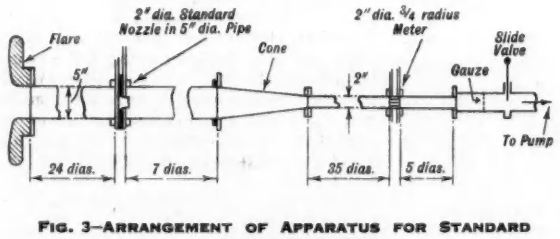


FIG. 3—ARRANGEMENT OF APPARATUS FOR STANDARD CALIBRATION TEST

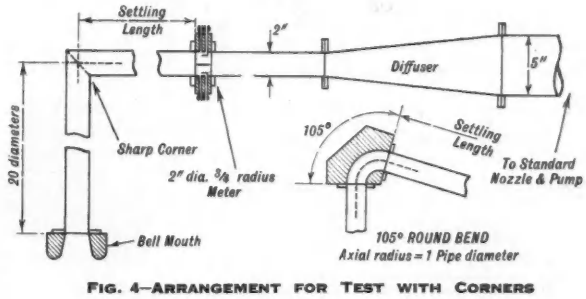


FIG. 4—ARRANGEMENT FOR TEST WITH CORNERS

CONCLUSIONS

The flow meter described in this article may be expected to have the following advantages :—

It is a compact and simple design suitable

† The static holes for the instrument with fixed pitot tubes can lie on the same diameters as the pitot tube mouths if the pitot tube diameter is small in relation to $R/4$.

for manufacture as a standard unit to suit internal pipe diameters ranging from ½in diameter upwards.

It has negligible loss.

The calibration coefficient is constant for varying velocity distributions arising from change of Reynolds number or other causes.

It will indicate asymmetry of flow and take account of it. It can therefore be used close behind bends or changes of section and thus avoids the necessity of a long calibration pipe. For good accuracy a honeycomb element should be placed behind the last bend or change of section to reduce swirl and asymmetry.

The three-quarter radius position of the pitot tubes is close to the point where the contribution to the flux is greatest, which means better accuracy than can be obtained with a central pitot tube if irregular velocity distributions are encountered. On the other hand the velocity fluctuations are greater in this position, which makes the manometer more difficult to read.

It is suitable for mean speeds above 40ft per second, and is particularly suitable for high speeds.

By suitable choice of size of unit, it should meter any flow greater than about 3 cubic feet per minute.

The more elaborate versions with traversing pitot tubes can provide their own calibration in situ.

Its chief disadvantage appears to be that it cannot be used in its present form in dust or soot laden air streams or in fluids containing solid particles because of the danger of clogging.

It would seem that the instrument is particularly suitable for metering the airflow in boundary-layer control experiments in wind tunnels, and in flight, where long calibration pipes cannot be used and low losses are required.

Appendix‡

This note gives the results of some experiments with a flow meter of the "three-quarter radius pitot tube" type which has been in use in the Aerodynamics Division, N.P.L., for the approximate metering of airflow in boundary-layer control experiments. The flow meter consisted of four 0·035in diameter hypodermic tube pitots in a 2in diameter pipe, and was calibrated by means of a 2in standard nozzle in a 5in diameter pipe, which was supplied by the Engineering Division, N.P.L., and also, for the smallest flows, by a rotameter whose calibration was known.

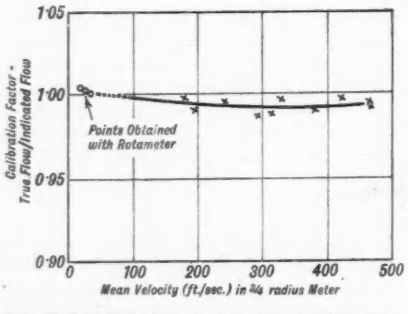


FIG. 5—CALIBRATION WITH LONG STRAIGHT SETTLING LENGTH

Besides the straightforward calibration of the instrument for rectilinear flow, some additional tests were made to determine the effects of various settling lengths with two types of bend placed upstream.

The mass flow through the standard nozzle was obtained from the measurements of the pressure difference across the nozzle and the static pressures upstream of the nozzle. The mean static pressure in the flow meter was observed by inter-connecting the four static holes to give a single reading. The four pitot tubes were similarly treated. The flow meter readings were evaluated by assuming that the velocity indicated by the pitots (obtained using the compressible-flow tables of A.R.C. 9933) was the mean across the pipe.

Calibration in Rectilinear Flow.—In this calibration, a settling length of 35 diameters of the 2in pipe was used upstream of the flow meter, Fig. 3.

The results are shown in Fig. 5. The rotameter was used to obtain points when the mean speed was below 40ft per second, and the standard nozzle when the speed was greater than 150ft per second. Some additional measurements were obtained with the standard nozzle for mean pipe velocities less than 150ft per second, but owing to the orifice Reynolds number being less than the limiting value, the results were not reliable. Except at the low speeds, the calibration curve is so nearly flat that a constant factor of 0·992 would give results within ±0·6 per cent over the whole of the speed range from 100ft to 450ft per second.

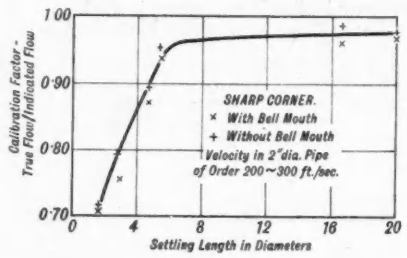


FIG. 6—RESULT OF TEST WITH SHARP CORNER

Calibration Variation with Settling Lengths After a Corner.—The positions of the flow meter and the standard nozzle were reversed for the second series of tests (Fig. 4). It was first established that the rapid diffusion from the 2in to the 5in pipe had no effect. Then a sharp right-angled corner or a 105 deg. bend of radius equal to one pipe diameter (2in) was introduced upstream of the meter which was then tested with various straight settling lengths. Upstream of the bend, there were 20 diameters of straight pipe.

The relation between the calibration factor and settling length is shown in Figs. 6 and 7, which suggest that the minimum permissible settling length, below which the calibration varies rapidly, is 6 diameters for the sharp corner and 9 diameters for the 105 deg. bend. Reducing the angle of the bend would improve the flow considerably and allow a shorter settling length to be used. The calibration varies little for settling lengths above 15 diameters.

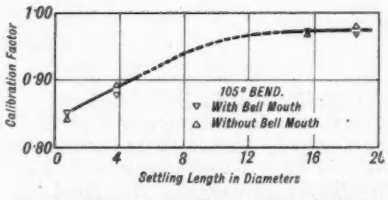


FIG. 7—RESULT OF TEST WITH ROUND CORNERS

The bend was also tested with three internal guide vanes. These reduced the losses, but the variation of the calibration factor with settling length was very erratic, presumably owing to the three-quarter radius tubes being in the wakes of the vanes. The distribution of velocity in the tube could be improved by inserting a fine mesh honeycomb or gauze, and this is desirable if the flow meter is used close behind a bend.

Conclusions.—The tests show that the flow meter is a very satisfactory instrument if used with a permanent settling length of straight pipe not less than 15 diameters long. As the calibration depends on the precise location of the pitot tubes, each instrument should be calibrated separately if intended for accurate work.

For an approximate measurement of the flow, the flow meter can be used much closer to a sharp bend than can a central-pitot type of meter; it is probably as good as an orifice meter or nozzle for these conditions, and offers considerably less resistance to the flow.

‡By N. G. Gregory, of the Aerodynamics Division, The National Physical Laboratory.

References

[1] E. Ower, "The Measurement of Airflow." Chapman and Hall.

[2] A. D. Young and J. N. Maas, "The Behaviour of a Pitot Tube in a Transverse Total Pressure Gradient," R. and M. 1770, 1936.

[3] S. Goldstein, "Modern Developments in Fluid Dynamics," Vol. I, page 252.

Productivity Report on Electricity Supply

THE Anglo-American Council on Productivity issued, yesterday, the report of a visit to the U.S.A. in 1949 of Productivity teams representing the generation and distribution sides of the British Electricity supply industry. In their search for means of increasing the productivity of the industry the teams found that the difference between American and British practice consisted mainly of a number of small items.

The report accepts the view that Britain's economic recovery depends largely upon the provision of sufficient generating capacity to meet present and future demands of industry. Accordingly, not only should new plant be provided as rapidly as possible, but existing plant should be fully utilised, first by reducing outages to minimum and, secondly, by improving the load factor.

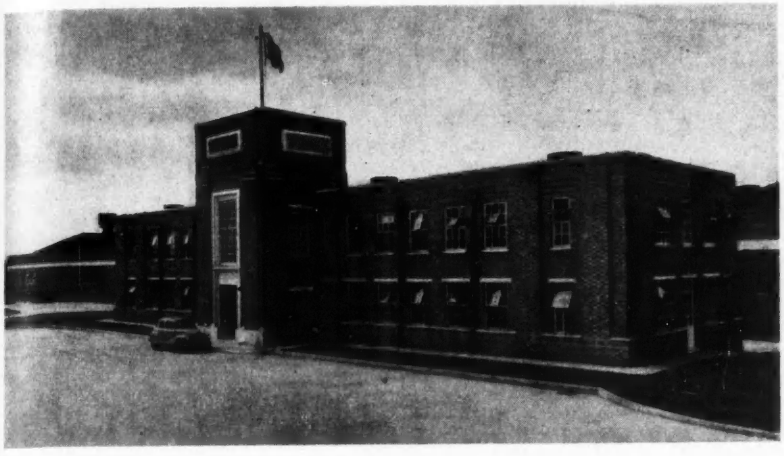
In technical development the report finds that the U.S.A. is ahead of Great Britain: factors that contribute towards steadily improving efficiencies and reduced costs per unit in the U.S.A. include the use of larger generating sets (sets of 100MW being commonplace), higher steam pressures and temperaturers, unit operation, centralised control and higher load factors. One result is a very marked economy in the use of manpower at new stations.

Wide differences in the speed of installation of new plant are referred to in the report. American stations are generally completed in little more than half the time required for similar British stations. The speed of American construction is due to the careful organisation and planning of the job, the high rate of output from the manufacturers and the fact that no obstacles are placed in the way of new projects and the choice of sites.

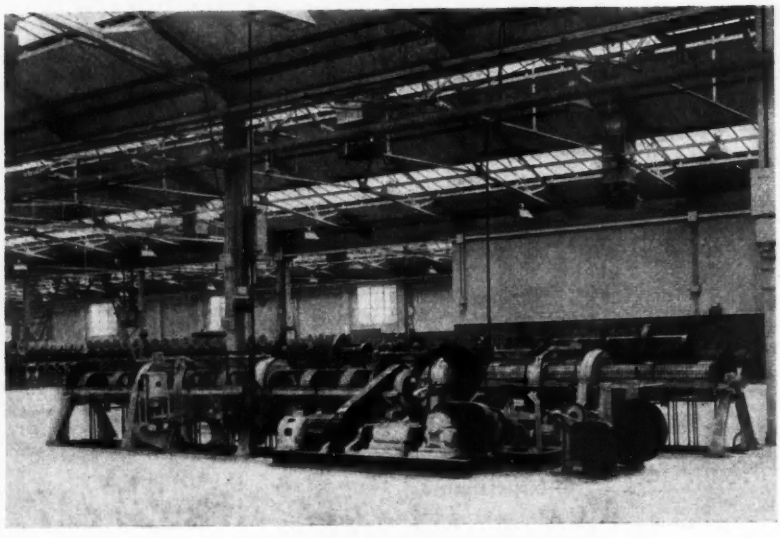
In American practice preventive maintenance makes a major contribution towards reduced outage. High boiler availability and efficiency is encouraged by maximum on-load inspection and maintenance, consistent high quality of coal, careful combustion control and organisation of overhauls. Similarly, high turbine availability is achieved by strict standards of balance and alignment, reduction in the number of smaller working parts, careful control of running up and load changing, and organisation of overhaul with rapid opening up of the sets. Highly developed fault repair organisations, capable of carrying out "hot line" maintenance and tower painting on lines up to 220kV help to maintain high standards of continuity of supply in spite of the high lightning incidence and the strict economy that is exercised in distribution system design.

Copies of the report (price 3s. 6d. post free) can be obtained from the Anglo-American Council on Productivity, 21, Tothill Street, S.W.1., or the British Electricity Authority, Great Portland Street, W.1.

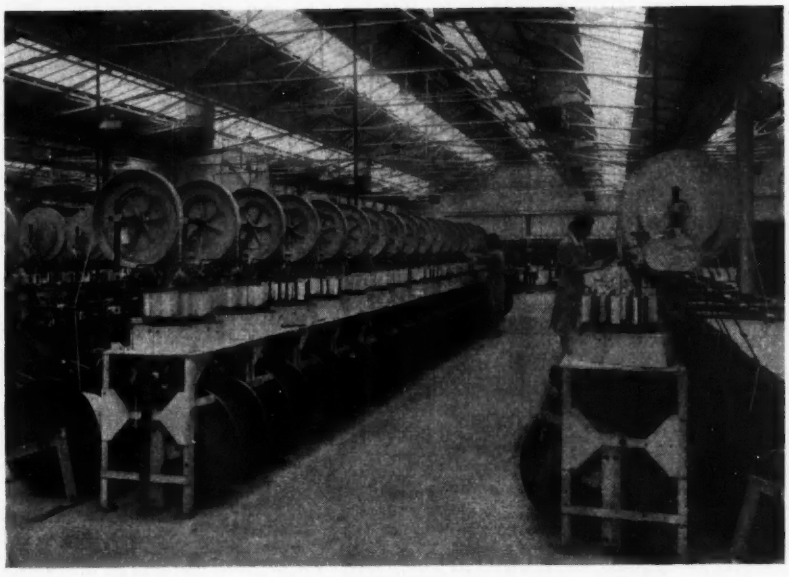
HENLEY CABLE FACTORY, BIRTLEY



ADMINISTRATIVE BUILDING AND CABLE WORKS



STRANDING MACHINES



CABLE BRAIDING MACHINES

A New Cable Factory at Birtley

AN important contribution to the production of Henley electric cables is to be expected from the Company's new factory at Birtley, Co. Durham which was formally opened on October 16th. The new factory occupies a 45 acre site, with a main road frontage of 1300 yards, about six miles south of Newcastle-upon-Tyne. Although active planning began in January, 1946, site work was not started until June, 1947. Plant began to be installed early in 1950 when the main buildings were ready.

Our first illustration shows the administration block immediately in front of the main factory which comprises a single-storey building covering a floor area of about nine acres. It is laid out so that work can flow generally from the raw material stores at the west end of the building to the warehouse space at the east end, all the manufacturing processess being carried out in the intervening space. The machinery being installed for this purpose includes wire drawing plant, tinning machines, stranding and bunching machines, Banbury rubber mixers, rubber mills, three-bowl calenders, machines for rubber covering, taping and braiding, lead presses and armouring machines. Of particular interest were the rubber extruding machines with provision for continuous vulcanisation—a process which minimises intermediate handling. Stranding machines and braiding machines are shown in two of the accompanying illustrations which give some impression of the arrangements for lighting and ventilation in the main factory.

Stale air is extracted by natural draught through 180 Robertson type ventilators designed to provide eight changes of air (each involving up to 12,000,000 cubic feet), per hour. Fresh air can be drawn into the building for circulation unheated or steam heated. Artificial lighting in the main factory is achieved by a mixture of tungsten filament and mercury vapour lamps which give, economically, a near-daylight effect.

The total electricity demand is made up of a lighting load of about 500kW; a variable heating load for annealing furnaces, tinning baths and lead presses etc.; and individual motor drives varying from fractional h.p. motors up to 200 h.p. motors for the heavy mixing mills. A supply for the total installed capacity of 4500kVA is taken at 20kV from the public system, through an incoming switch house and three factory substations.

Institution of Mechanical Engineers

ON Thursday, October 19th, the Institution of Mechanical Engineers held its annual dinner and on the following evening its President, Dr. S. F. Dorey, presented his address. At the dinner the Toast of the Institution was proposed by Lord Portal. He remarked that to-day a great deal of attention was being given to production problems and much energy was being expended upon research. But was enough attention being directed to engineering design? In reply Doctor Dorey referred to the recent work of the Institution and particularly to the recent conference of Commonwealth Engineering Societies at Johannesburg. The toast of the guests was proposed by Mr. A. C. Hartley. Responses were made by Vice-Admiral Sir Michael Denny, Controller of the Navy, and Sir Ronald Garrett, Chairman, Lloyd's Register of Shipping. Sir Michael felt that a mechanical engineering training was essential for naval officers although at the moment the navy had turned away from that system of education. The Admiralty was now sponsoring the development of designs of propulsion equipment that were a considerable advance upon anything at present in naval or mercantile use. It was bringing into marine use plant with "land" performance. The development of a very advanced design of "lightweight" diesel engine was being sponsored. Gas turbine development was also in hand. But before that prime mover could be a success it must run off residual fuel. Doctor Dorey's address was concerned with his work with Lloyd's Register of Shipping.

British Patent Specifications

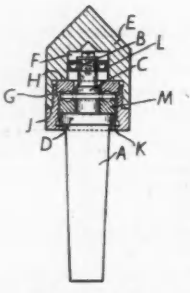
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

TOOLS AND WORKSHOP APPLIANCES

640,764. August 12, 1948.—Revoluble-Headed Centre for Lathe and Analogous Uses, George William Hazlewood, of 90, Great Hampton Street, Birmingham, 19.

The object of the invention is to provide an improved and simple construction, particularly convenient for replacing its worn ball bearing units. In the accompanying drawing the solid shank *A* is provided with a forward peg *B* behind which is a middle portion *C*, and a collar *D* of a much larger diameter, these parts being all cylindrical and concentric to the shank and rigid with it. The head *E* is hollow and has an inner plain chamber *F*, and a larger diameter outer



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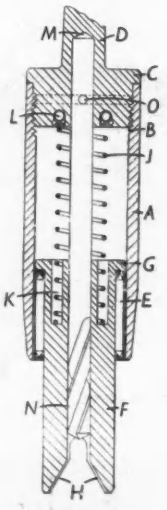
chamber *G*, which is internally screw threaded, both chambers being cylindrical and parallel with each other and concentric to the head *E*. A circular shoulder *H* between the two chambers is provided. Screwing into the outer chamber *G*, hard up to an abutment shoulder J, is a sleeve-like ring nut *K*, which, when applied to the outer chamber *G* and over the shank *A* becomes a rigid part of the head *E* and always revolves with it. A journal ball bearing *L* operates between the inner chamber *F* and the forward peg of the shank, and it is a feature of the invention that this ball bearing is secured upon the peg by mechanical devices, such as a washer and a screw pin, to be easily renewable on the peg. A thrust ball bearing *M* operates between the abutment shoulder of the head and the collar *D* of the shank and over the middle portion *C* of the shank and within the sleeve-like ring nut *K*, and it is a feature of the invention that the bore of this ring nut fits the inner ring of the bearing tightly, and the outer ring and the ball cage and the collar loosely, but accurately.—*July* 26, 1950.

640,862. September 15, 1948.—An Improved Drilling Device, Thomas Wass Flory, of 5, The Manor House, Earls Avenue, Folkestone, Kent.

This invention constitutes an improvement on, or modification of, the invention set forth in Specification 615,918. In the accompanying drawing the drilling device comprises a tubular body *A* threaded internally at its rear end as at *B* to receive the head *C* of a drill holder *D*, of, for example, the Morse taper type, and at its other end it has fitted thereinto an antri-friction bearing *E* of the Torrington type. An axially bored drill guide F having a peripheral flange *G* at its inner end is slidable in the tubular body *A* and through the Torrington bearing *E*, and at its outer end it is formed with a conically flared V-mouth as at *H*. Within the tubular body *A* is a coiled spring *J* abutting at one end against the inner end of the drill guide *F* (which is formed coaxially with a circular recess *K* to receive the end of the spring *J*), and at its other end against a thrust bearing *L* in the inner end of the head *C* of the drill holder *D*. The head of the drill holder is formed with a coaxial recess *M* of a diameter slightly greater than that of the butt end of the shank of the drill *N* to be used which is held loosely in the recess *M* by a cross pin *O* slidable freely in a passage through the threaded part of the head, so that it is restrained against end se movement when the head is screwed into the body. The device is fitted into a drilling machine and is lowered. The recess in the end of the drill guide first centralises the work under the drill and then, as lowering is continued, the drill guide is pressed back into the tubular body against the action of the spring, and the drill advances into, and drills, the work. During this operation the drill holder, the drill and the tubular body are rotated; the drill guide is restrained against



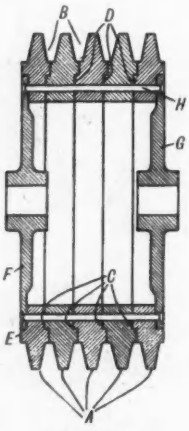
No. 640,862

rotation by the engagement of the recess in its end with the work; the Torrington bearing permits relative rotation and axial movement between the drill guide and the tubular body; and the thrust bearing at the inner end of the drill holder permits relative rotation between the drill holder and the end of the spring, while the floating of the shank of the drill in the drill holder ensures the accurate movement of the drill in the direction of its axis, especially when the drill is following a previously drilled pilot hole.—*August* 2, 1950.

MISCELLANEOUS

641,291. February 6, 1948.—Improved Vee-Belt Pulley, Herman Albert Jensen, of Lyngbyvej 431 B, Gentofte, Denmark; Erik Christiansen, of Knud Rasmussensvej 22, Soborg, Denmark, and Borge Martins, of Callisensvej 2, Hellerup, Denmark, all Danish.

The object of the invention is to provide means for producing a comparatively light vee-belt pulley, which, notwithstanding its lightness, possesses considerable resistance to deformation. Referring to



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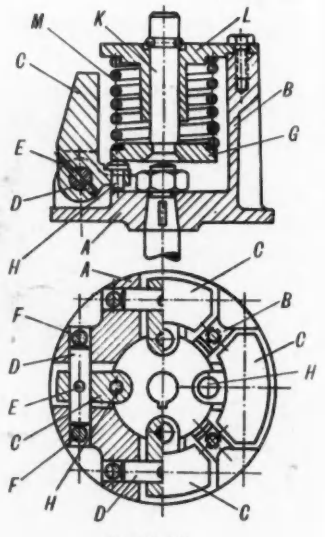
the drawing, the vee-belt pulley shown comprises five rings arranged side by side, indicated by *A*. The periphery of each of these rings is so formed that in combination with adjacent rings grooves *B* for vee belts are formed. Below the part forming the belt groove each ring has on its one side an annular groove *C*, and four of the rings have on the opposite side an annular projection *D* that engages the annular groove *C* in the adjacent ring, thus centring these rings relatively. The outermost ring has instead of an annular projection an annular recess *E* by means of which it is centred on a hub disc *F*. A similarly formed hub disc *G* is inserted within the annular groove *C* of the other outermost ring *A*, thus centring this ring in relation to the hub. The rings *A* and the hub discs *F* and *G* are assembled to a unit by means of a number of bolts *H*. The above described manner of construction only serves to illustrate the invention, as it is obvious that in the assembly shown any number of rings can be used requiring only correspondingly formed bolts.—*August* 9, 1950.

640,728. September 5, 1947.—Improvements in or relating to Centrifugal Governors, Egon Niedermayer, an Austrian, of 30, Herrandgasse, Graz, Austria.

This invention relates to centrifugal governors used in fuel injection pumps for internal combustion engines where it is particularly desirable that the outer diameter of the governor be as small as possible owing to the restricted space available. In the accompanying drawings the governor hub *A* is formed with narrow extensions *B* between which the flyweights *C* are arranged, the flyweights being supported in the governor hub by spindles D fixed to the flyweights by the pins *E*. Axially these spindles are secured against displacement by pins *F* which are held in the governor hub by split



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pins or cotters. The end faces of the spindles *D* are rounded so that they and the pins *F* will only make point contact. This design prevents any lateral contact of the flyweights and the governor hub, thereby reducing friction to a minimum so that there is no need to surface finish the flyweights and the bearings, and the regulation becomes more sensitive and accurate. The transmission of the force from the flyweight *C* to the sleeve *G* is made by a pressure stud *H* retained in a lever arm of the flyweight, the sleeve being connected to the governor shaft *K*. At the same time the stud acts as a stop limiting the inner position of the flyweights in regard to the governor hub. Another advantage of the invention is that, regardless of the mass of the flyweights, the minimum distance of the sleeve *G* from the body *A* is exactly determined by the length of the stud *G*. In this case, too, the expensive finishing of the flyweight surfaces is replaced by a simple drilling operation. The extensions *B* arranged between the flyweights *C* are provided with a supporting plate *L* between which and the sleeve *G* is retained the governor spring *M*.—*July* 26, 1950.

"Colonial Geology and Mineral Resources."—We have received recently a copy of the first issue of a quarterly journal with the above title, which is obtainable from H.M. Stationery Office, price 5s. The journal is prepared by the Directorate of Colonial Geological Surveys and, together with a journal entitled *Colonial Plant and Animal Products*, will now be issued in place of the well-known *Bulletin of the Imperial Institute* which has been abandoned. The first volume contains interesting and authoritative articles on colonial geological topics, including an article by F. Dixey, Director of the Survey, which explains the scope and activities of the Directorate of Colonial Geological Surveys, which was formed in 1947.

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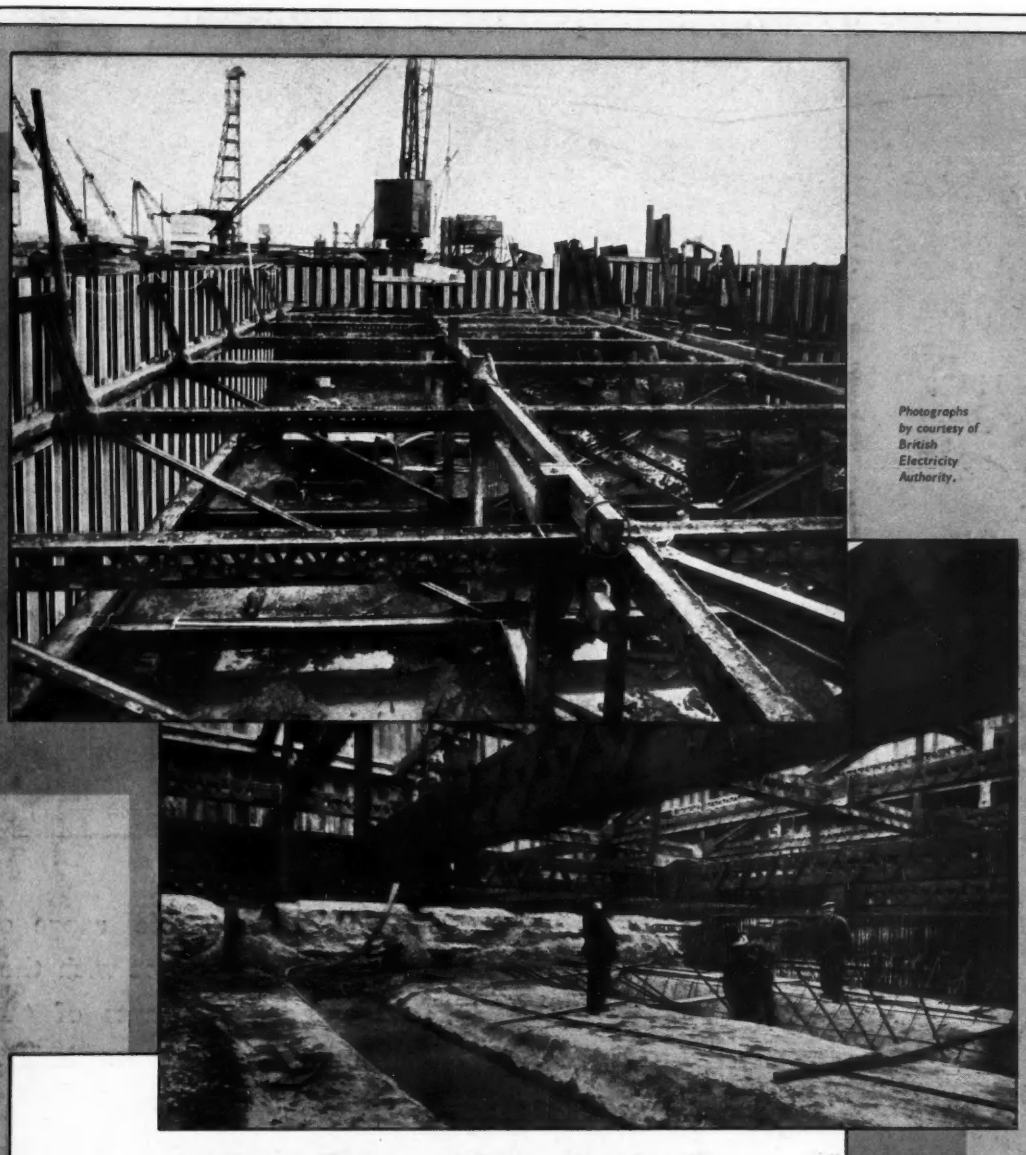

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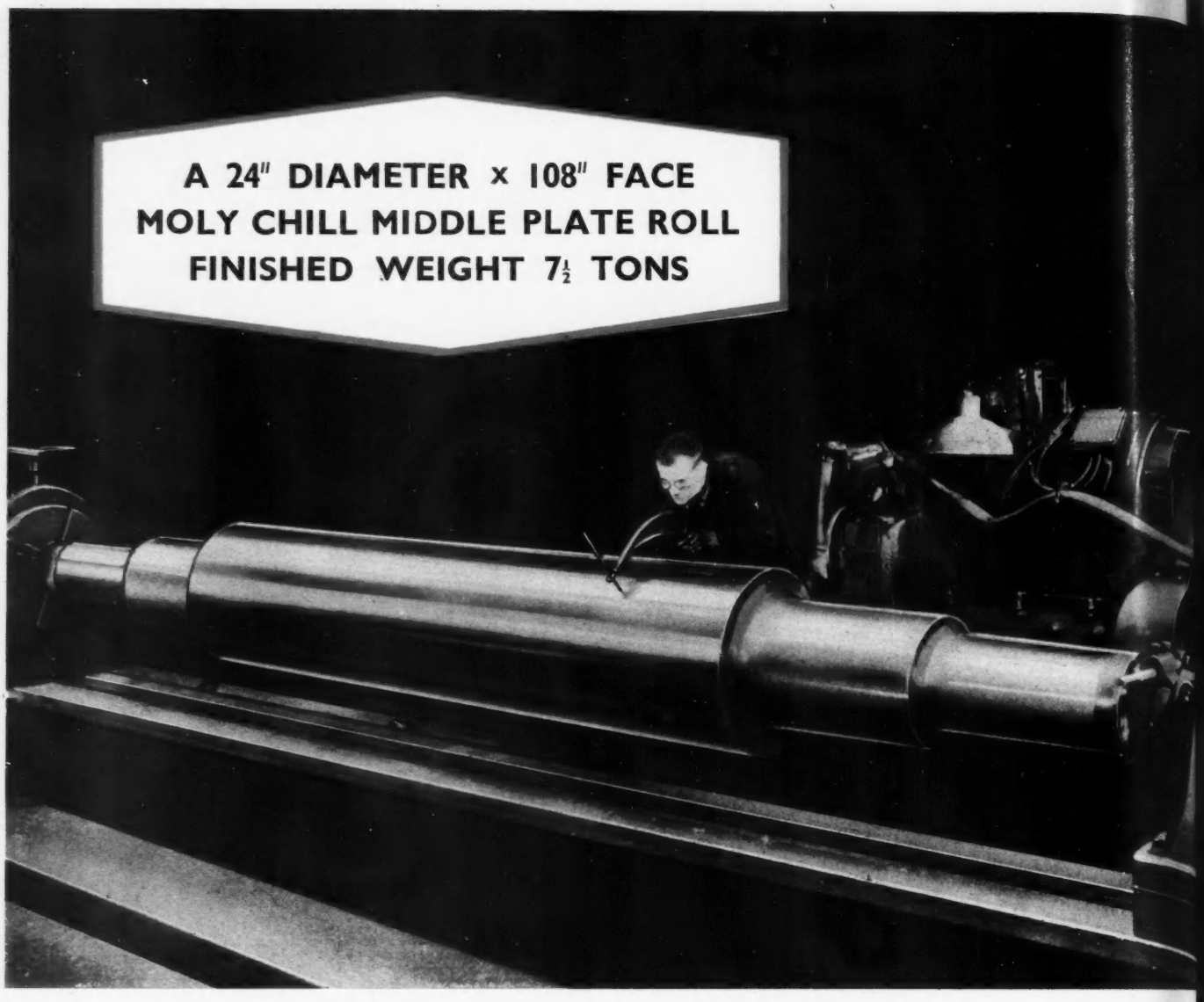

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